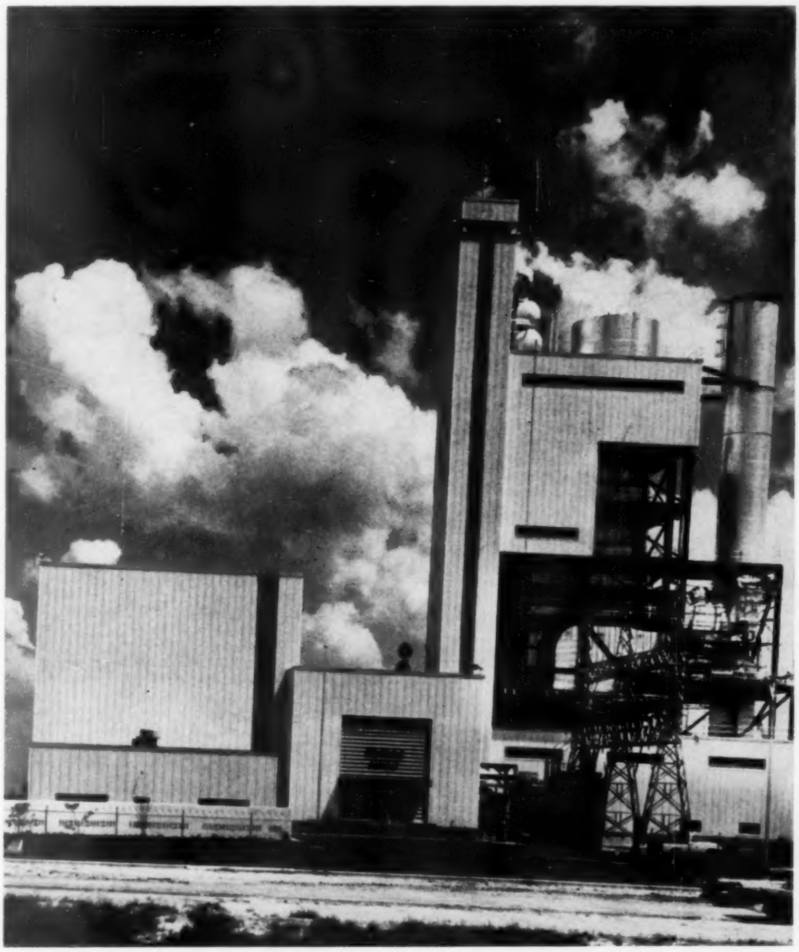
Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION



ember 1961

Furnace Protection and Burner Controls

Assessing Pulverizing Mills

Power Plant Clinic

Turbine Controls

How C-E helps the pulp and paper industry save more than 50 million pounds of chemicals a day

Most of the world's paper is made from the cellulose contained in wood. An involved series of cooking processes and chemical baths is necessary to separate the usable cellulose from the other wood ingredients. Vast quantities of chemicals are required and, because of this, the economic well-being of the pulping industry literally depends on the efficient reclamation and re-use of these chemicals.

The C-E Chemical Recovery Unit — at home in pulping plants the world over—not only solves the recovery problem, but at the same time, produces much of the steam needed to cook and process the pulp which the chemicals helped make.

The residue from the pulping process, a soupy mixture of chemicals, organic matter and water, is fed into the Chemical Recovery Unit which burns the organic matter as fuel. The heat evaporates the water. The unburnable chemicals fall to the furnace floor as molten smelt. The smelt flows from the furnace and is then processed and the chemicals made ready for re-use. And the steam generated by the heat from this process is sufficient to meet a sizable portion of the pulp mill's needs.

Today, C-E Chemical Recovery Units are installed or on order in the U. S., Argentina, Canada, Cuba, East Pakistan, Finland, India, Mexico, Portugal, Republic of the Philippines and Taiwan. In the aggregate, they have a recovery capacity in excess of fifty million pounds of chemicals a day. Without such recovery capabilities, the structure of the pulping industry would be considerably different—and the cost of paper would be much higher.

COMBUSTION ENGINEERING

GENERAL OFFICES: Windsor, Conn.
NEW YORK OFFICES: 200 Madison Avenue, New York 16

C-345

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

volume 33 number 6 **December 1961**

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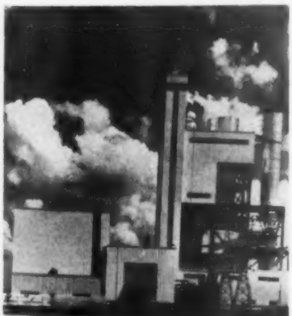
Printed in U. S. A.

COVER PHOTO

Daylight view of the beautiful new Nichols Station of the Southwestern Public Service Co., near Amarillo, Texas



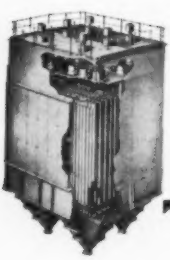
EXPERIENCE

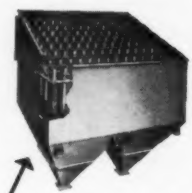
...OUR PLUS
to solve industry's toughest gas cleaning problems

Nearly 50 years' experience as the leading engineers and manufacturers of gas cleaning equipment.

Hundreds of installations in various industries throughout the world, collecting dusts, fumes and mists, and cleaning gases from many sources. Here is partial list of applications.

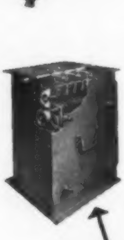
POWER—Fly ash collection
STEEL—Basic oxygen, sintering and open hearth dust collection.
PAPER—Sodium salts recovery
CHEMICAL—Aerosol and acid mist collection
METALLURGICAL—Metallic dusts and fumes collection
CEMENT—Kiln and finish mill dust collection
GYPSUM—Kettle, mill and dryer dust collection
PETRO-CHEMICAL—Catalyst recovery
RUBBER—Carbon black collection

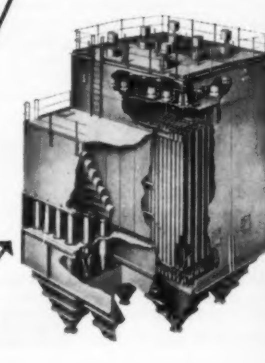




High Efficiency, Reliable Low Operating Cost, Low Maintenance Cost, Industrial Gas Cleaning Equipment:

Cottrell Precipitators
Collection efficiencies of over 99% are being obtained and guaranteed with Research-Cottrell Precipitators.





Cyclo-trell Mechanical Collectors
These low first cost high efficiency collectors provide greater separating forces and reduction in over-all resistance (pressure drop) than other types of mechanical collectors. They are available in multiple tube and involute designs.

Combination Electrostatic-Mechanical Collectors
Under some conditions the most economical solution to a gas cleaning problem is a combination of the Cyclo-trell ahead of or after a Research-Cottrell Precipitator.

Electrostatic Air Cleaners
Custom air cleaners such as those Research-Cottrell developed for the Navy's nuclear submarines are available for special applications.

Flooded Disc Scrubber
Adjustable—High efficiency. No increase in pressure drop, even at gas flows 50% over normal. No nozzles to wear or plug up.

Complete System Evaluation
Research-Cottrell's pioneering work and continuing experience with three-dimensional model studies has enabled us to appraise the complete gas cleaning system and engineer the products which guarantee high efficiency performance in every application.

If you have a gas cleaning problem that requires an economical solution, contact Research-Cottrell today.

Research-Cottrell

COTTRELL ®

RESEARCH-COTTRELL, INC. Main Office and Plant: Bound Brook, New Jersey
Representatives in principal cities of U. S. and Canada

MEMBER OF THE INDUSTRIAL GAS CLEANING INSTITUTE

RC-224

Diamond developed for more economical power

THE NEW DIAMOND DURA•PORT

UNMATCHED RELIABILITY FOR HIGH PRESSURE WATER LEVEL INDICATION

Here's Diamond's *newest* multi-port bi-color water gauge. It's the DURA-PORT . . . proved superior by twelve months' intensive field testing by 11 leading utilities.* Designed specifically for operating pressures from 1051 to 3000 psi, the DURA-PORT assures dependable, easy-to-see water level readings with up to 80% less maintenance. Here's why:

1. New port sealing design . . . clamping load on glass is limited to that imposed by gasketing compression . . . all but eliminates glass breakage caused by clamping overload . . . slashes port replacement expense . . . (no glass breakage experienced with test gauges to date).

2. New gasketing arrangement . . . provides ample resiliency for continuous seal under expansion . . . no torque wrench needed!

3. Fewer coverplate screws . . . four socket head cap screws — tightened with standard hex wrench — firmly secure individual ports . . . cut port replacement time by more than one half.

4. 1" dia. ports . . . largest on any gauge designed for high pressure applications. Combined with new high-intensity illuminator, larger ports assure brighter, more distinct water level indication over longer distances . . . far better than any design previously available.

5. Two vision lengths . . . 18" (7 ports) and 12¼" (5 ports).

6. Temperature equalizing design . . . recommended for pressures 2000 psi and over; reduces error caused by temperature differentials by as much as 75%.

7. Choice of four viewing hoods . . . 90° reflector, open front stub, direct reading or direct reading with exclusive new wide-angle vision.

All Diamond gauges are steam tested and when they leave our factory are ready for operation after normal warm up procedure.

Bulletin DP-2607 has complete details... call write or wire for your copy . . . today.

*names and test results on request

DIAMOND POWER SPECIALTY CORPORATION
LANCASTER, OHIO
Diamond Specialty Limited • Windsor, Ontario

To function at optimum efficiency and thereby provide the lowest possible steam costs, central power stations must burn coals that deliver a uniformly high heat content.

Valley Camp Quality Coals are famous for meeting the requirements of central power stations. They are completely prepared and thermally dried under exact quality controls, ready for shipment in sizes and consist to specification.

Our combustion engineering service is available to analyze your problem, to help you get optimum efficiency with Valley Camp Quality Coals.

THE VALLEY CAMP COAL COMPANY

Western Reserve Building • Cleveland 13, Ohio

SUBSIDIARIES —

Great Lakes Coal & Dock Co., Milwaukee, Wis. • Great Lakes Coal & Dock Co., St. Paul, Minn. • Fort William Coal Dock Co., Ltd., Fort William, Ont. • The Valley Camp Coal Co. of Canada Ltd., Toronto, Ont. • Kelley's Creek & Northwestern Railroad Co. • Kelley's Creek Barge Line Inc. • Pennsylvania & West Virginia Supply Corp.

SALES OFFICES —

Philadelphia • Baltimore • Buffalo • Pittsburgh • Wheeling • Cleveland • St. Paul • Cincinnati • New York • Milwaukee • Superior, Wis. • Fort William, Ont. • Toronto, Ont.

Compact Packaged Air Preheater being unloaded for installation on new 100,000 lb/hr boiler at Hoffmann-La Roche's Nutley, N. J. headquarters. In operation, it will increase the temperature of the combustion air 375°F—thereby increasing boiler efficiency by approximately 8%.

PACKAGED AIR PREHEATER

WILL RECOVER 330°F FROM NEW BOILER FOR HOFFMANN-LA ROCHE INCORPORATED

Hoffmann-La Roche, one of the leading producers of pharmaceuticals, vitamins and aromatic chemicals, specified a Ljungstrom Packaged Air Preheater for their new boiler for three reasons: 1) This compact, preassembled unit is ready to run as soon as it's connected to the power line and ducts—no extra installation or erection costs; 2) The unit occupies only about 450 cubic feet of space but will cut boiler exhaust temperatures from 680°F to 330°F—for about 8% saving in fuel; 3) Savings in fuel alone—roughly 1% for every 40°F drop in exit gas temperature—can pay for the unit in two short years!

Packaged Ljungstroms are available in sizes for use on boilers in the 25,000 to 250,000 lb/hr range—can give you these same fuel saving advantages. For full information, write today for our 14-page Packaged Air Preheater booklet.

THE AIR PREHEATER CORPORATION

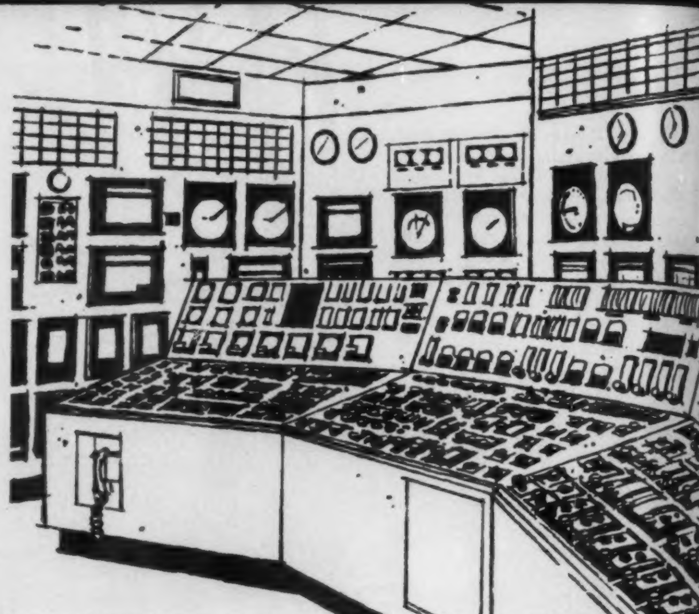
60 East 42nd Street, New York 17, N. Y.

FIRST SIMPLIFY...

First step to automation is to *simplify* the information now presented by a multitude of multi-record charts, gages, and annunciator lights. The Bailey approach gives the operator data he needs (logged periodically), keeps continuous watch on all variables, makes calculations where required, alarms when trouble threatens.

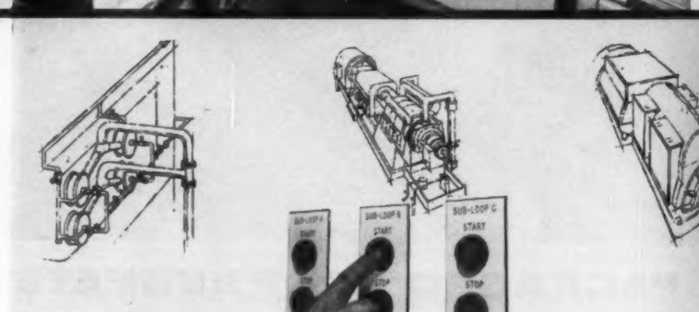
Bailey 700 Systems draw on the best available techniques, including analog and digital manipulation, trend recording, time sharing, scanning, alarming, calculating, controlling, and logging, as required to meet operating objectives.

Reliability of recorded data is increased ... operators can devote full attention to correcting off-normal conditions and improving operations. The system may include frequent performance calculations showing the contributions of each portion of the cycle to over-all performance so that faults and deterioration may be spotted and corrected.



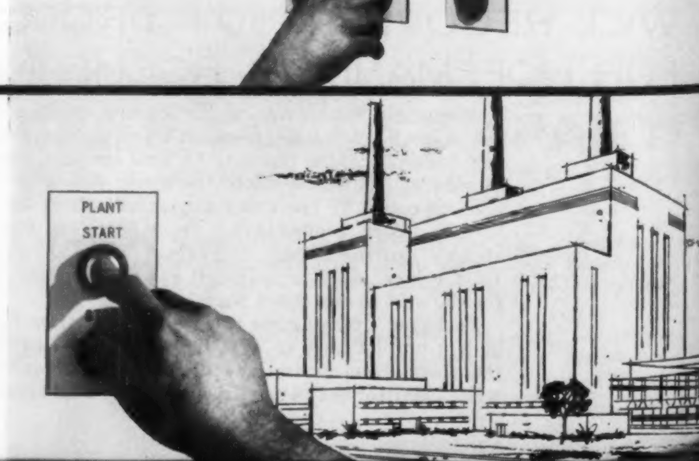
NEXT VERIFY...

Next verify the practicability of automation by extending supervisory controls, letting equipment perform more operating functions. Automate key systems, one at a time, by push-button-controlled subloops. This approach smooths the transition to complete automation.



THEN AUTOMATE

Final steps are: (1) consolidate supervisory controls, conventional controls, and subloops for full-range automatic operation once the plant has been placed on the line; and (2) add start-stop control to provide full automation.



first Simplify...

NEXT VERIFY...

THEN AUTOMATE

Bailey verified steps to automation mean benefits now... and increasing benefits as you go

Automation need not be an all-out commitment. Between today's conventional power-station control and the ultimate in automation are step-by-step advantages that can be gained—as individual problems are resolved.

This permits the final investment commitment only after satisfactory evidence that it is economically justified and practicable.

Bailey Systems concepts are embodied in the approach, "First simplify — next verify — then automate". The steps outlined here coordinate the best available techniques, including analog and digital, in Bailey 700 Systems designed — and expanded as desired — to the needs of the individual plant. They may be undertaken singly, in combination, or in entirety. System elements are composed of solid-state electronic modules providing the ultimate in reliability and flexibility.

Bailey 700 Systems are in operation today —or on order for installation—from coast to coast and all over the world. Ask your Bailey Engineer, or write for details. Bailey Meter Company, 1025 Ivanhoe Road, Cleveland 10, Ohio. In Canada — Bailey Meter Company Limited, Montreal.

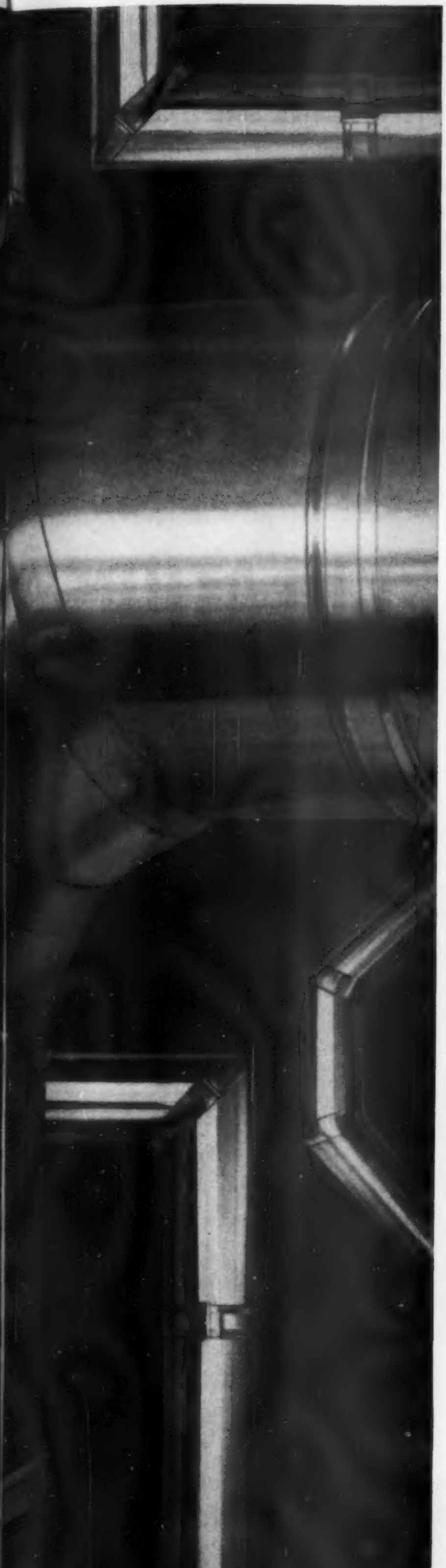
System concepts founded on 45 years of experience

21 out of 26 of today's "most efficient" steam-electric stations in the United States use Bailey Instruments and Controls*. This reflects the more than 45 years of Bailey developments devoted to improving the reliability of power-plant operation. These developments include experience in automation, dating from electrically operated boiler controls in 1924 and automatic start of boiler controls on steam-electric locomotives in 1936, to systems installations in operation, or under construction today, from coast to coast and throughout the world.

**Listed in Federal Power Commission Report S-143.* A 166-2

BAILEY METER COMPANY

700 Systems



Now! J-M Metal-On covers all the angles

WITH NEW J-M MITER-SEALS, YOU CAN USE METAL-ON TO INSULATE ELBOWS, BENDS, SWEEPS AND TURNS

Now you can protect your *entire* pipe-line system with Johns-Manville Metal-On®...the Thermobestos®, calcium silicate insulation prejacketed with weather-proof aluminum. Yes, even the most complex elbows, bends, sweeps and turns can benefit from the superior insulation of Metal-On.

J-M research has developed Miter-Seal®, a factory-made, preformed aluminum band. It has a clip at one end that can be tightened in a flash with a J-M Banding Wrench. *One* measurement, *one* cut, *one* application, and both insulation and jacket are applied. A quick turn of the Banding Wrench on the Miter-Seal completes the job! (See below.)

For full details, write to J. B. Jobe, Vice President, Johns-Manville, Box 14, N. Y. 16, N. Y. In Canada: Port Credit, Ont. Cable: Johnmanvil.

THE MATERIALS

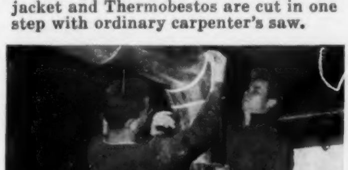
Miter-Seal

J-M Banding Wrench

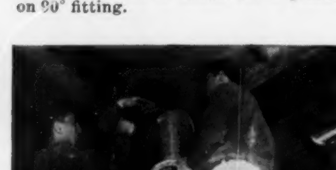
THE METHOD

Mitering section of Metal-On. Both jacket and Thermobestos are cut in one step with ordinary carpenter's saw.

Mitered section of Metal-On is placed on 90° fitting.



Miter-Seal sealing compound is placed in mitered joint.



Miter-Seal bands are applied and tightened to finish fitting.

JOHNS-MANVILLE

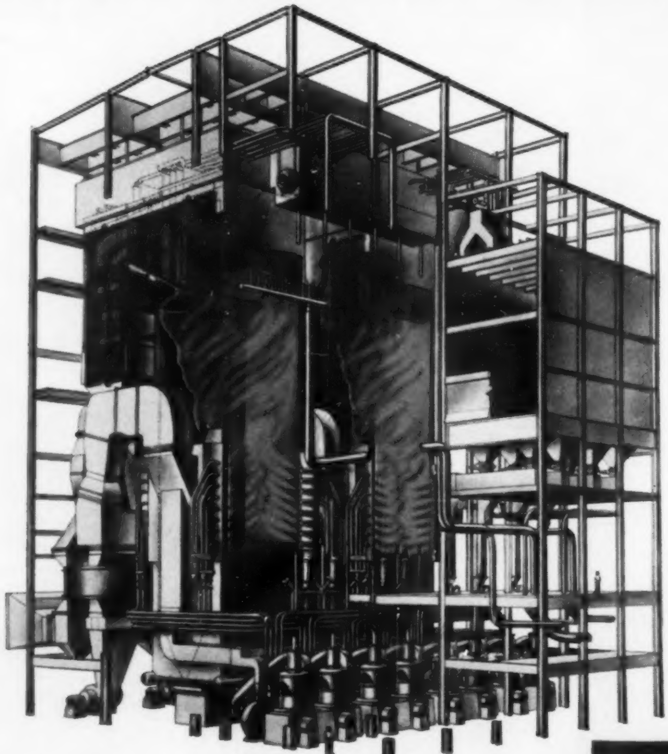
AN INSULATION FOR EVERY COMMERCIAL AND INDUSTRIAL USE

In 1950, the C-E Controlled Circulation Steam Generator was made available to the electric utility industry as a fully developed and proven design. Several units were ordered during the year and the first of these was placed in service in November, 1952.

In the intervening decade, the Controlled Circulation Steam Generator has achieved unparalleled acceptance in utility power practice the world over. To date, about 43,000 megawatts of Controlled Circulation capacity has been purchased for utility service at home and abroad. In addition to country-wide installations in the U. S., Controlled Circulation Steam Generators are now in service or under construction in Australia, Canada, England, France, Italy and Japan. Principal statistics are shown opposite and in the accompanying chart.

In the U. S., 37 utility systems have ordered units of this type for installation in 72 power plants located in 22 states. These systems have a total installed thermal capacity equal to more than 50% of the nation's total. Twenty-nine of these systems have ordered more than one unit, seven have ordered six or more and two have ordered twelve or more.

THE CONTROLLED CIRCULATION



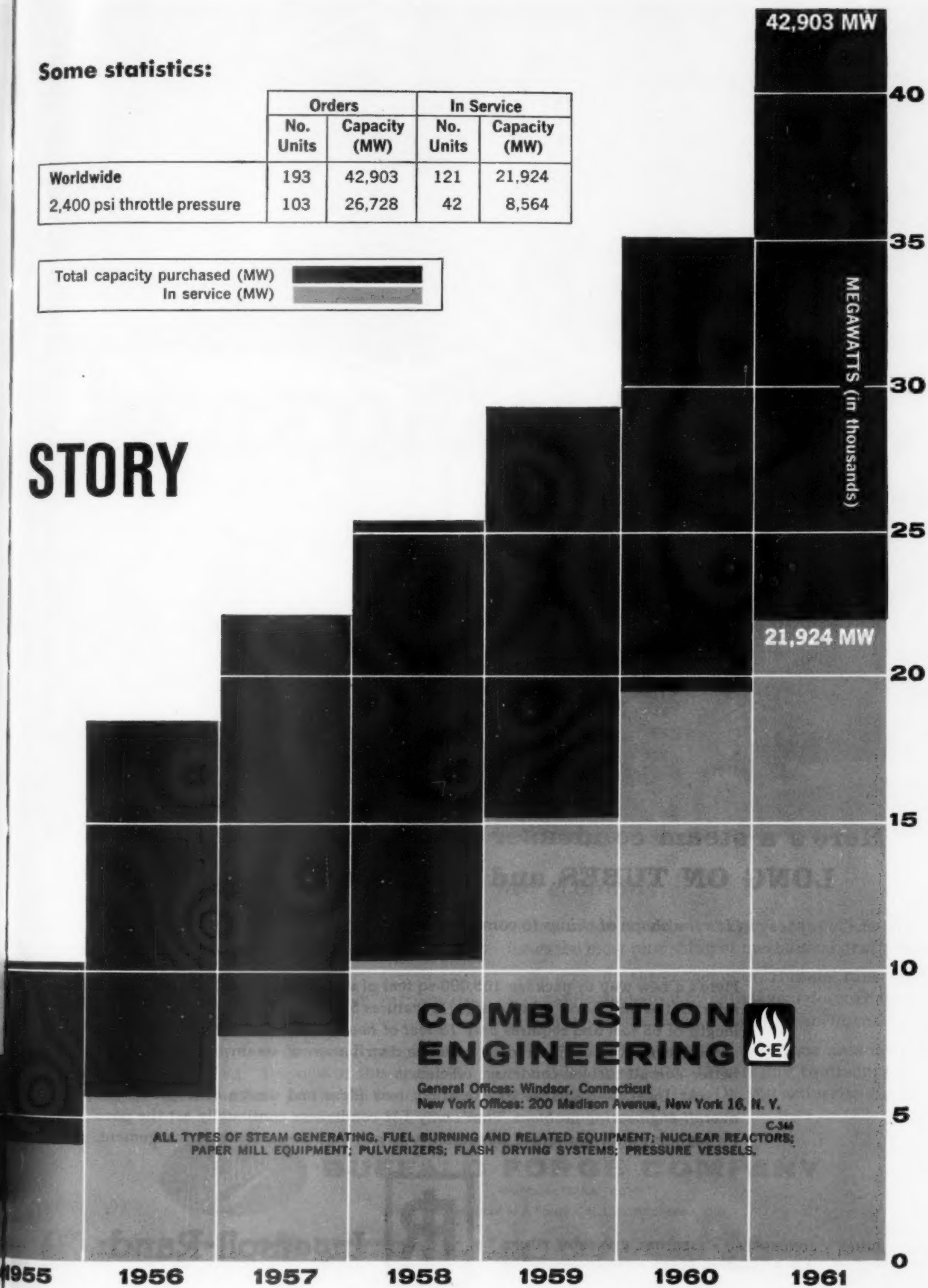
C-E CONTROLLED CIRCULATION STEAM GENERATOR
Controlled Circulation Units like the one pictured have achieved world-wide acceptance in high pressure power practice.

Some statistics:

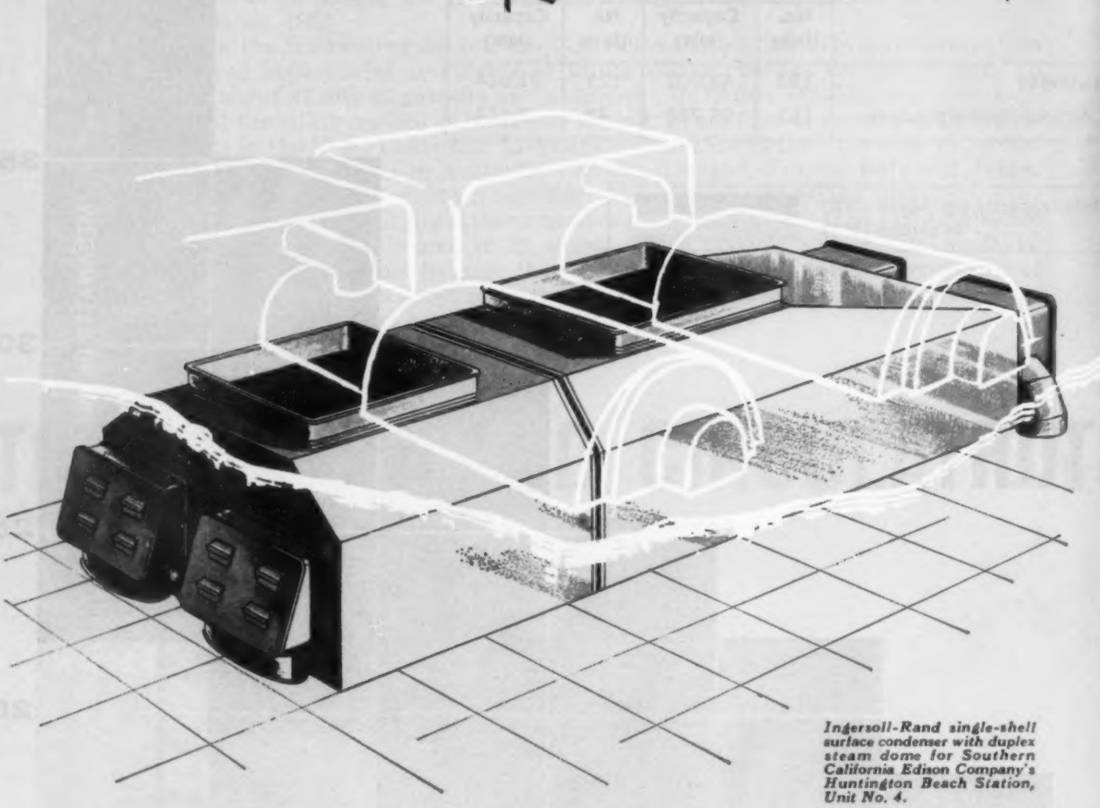
	Orders		In Service	
	No. Units	Capacity (MW)	No. Units	Capacity (MW)
Worldwide	193	42,903	121	21,924
2,400 psi throttle pressure	103	26,728	42	8,564

Total capacity purchased (MW)
In service (MW)

STORY



Adding new dimensions to engineering



Ingersoll-Rand single-shell surface condenser with duplex steam dome for Southern California Edison Company's Huntington Beach Station, Unit No. 4.

Here's a steam condenser that's LONG ON TUBES and SHORT ON HEIGHT

(It's the shape of things to come when capacity is high and head-room is low)

Here's a new way to package 105,000 sq feet of steam condensing surface. Many refer to it as our "Long John" design. It features 54 foot long tubes, has an overall length of 65 feet and requires *only 18 feet of headroom.* The offset duplex steam dome is specially engineered to optimize distribution of steam and provide for better overall turbine-condenser efficiency.

At Ingersoll-Rand we like to apply new ideas and design concepts to the *overall engineering problem.* That's why I-R condensers continually set the pace for highest performance and adaptability to any turbine-condenser arrangement.

PUMPS • CONDENSERS • EJECTORS & VACUUM PUMPS
AIR & ELECTRIC TOOLS • AIR COMPRESSORS

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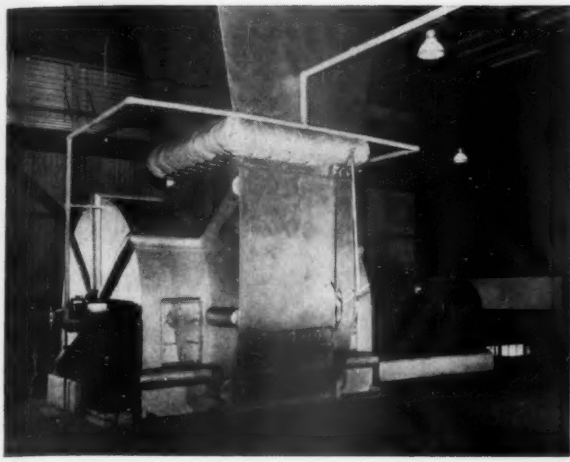
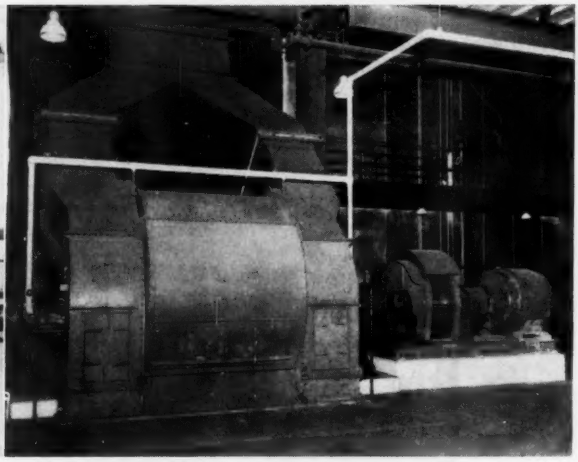
306A4 11 Broadway, New York 4, N. Y.



PERFORMANCE...



the practical measurement of fan economy

Like all capital equipment, the true economy of mechanical draft fans can be measured only in terms of performance.

"Lowest" initial cost and "promised" ratings are poor, often *costly* criteria.

'Buffalo' heavy-duty fans are quality-engineered to perform "as specified." Because of this engineering, 'Buffalo' fans use less power . . . require less maintenance . . . deliver extra years of efficient service in the most punishing of mechanical draft uses.

As a result, the economy of 'Buffalo' fans can be accurately measured by actual year-to-year savings in power, maintenance, and replacement costs.

The Buffalo representative in your area is an air handling specialist. It will pay to discuss your requirements with him. Or, you can write direct.

"Buffalo"

AIR HANDLING DIVISION

BUFFALO FORGE COMPANY

Buffalo, New York

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

'Buffalo' Air Handling Equipment to move, heat, cool, dehumidify and clean air and other gases.

'Buffalo' Machine Tools to drill, punch, shear, bend, slit, notch and cope for production or plant maintenance.

'Buffalo' Centrifugal Pumps to handle most liquids and slurries under a variety of conditions.

Squier Machinery to process sugar cane, coffee and rice. Special processing machinery for chemicals.

Copes-Vulcan automatic boiler control at Hammermill Paper Company

Gives good results on steam generator fired with hogged bark and coal

Here was an unusual problem of boiler control. Two solid fuels—hogged bark and bituminous coal—were to be burned in combination. The Riley steam generator, with nominal rating of 206,000 pounds per hour at 675 psig and 760 degrees F., was to deliver power and process steam to the same main header as all other existing boilers. Low steam costs and high boiler availability were a goal of the design and operating engineers.

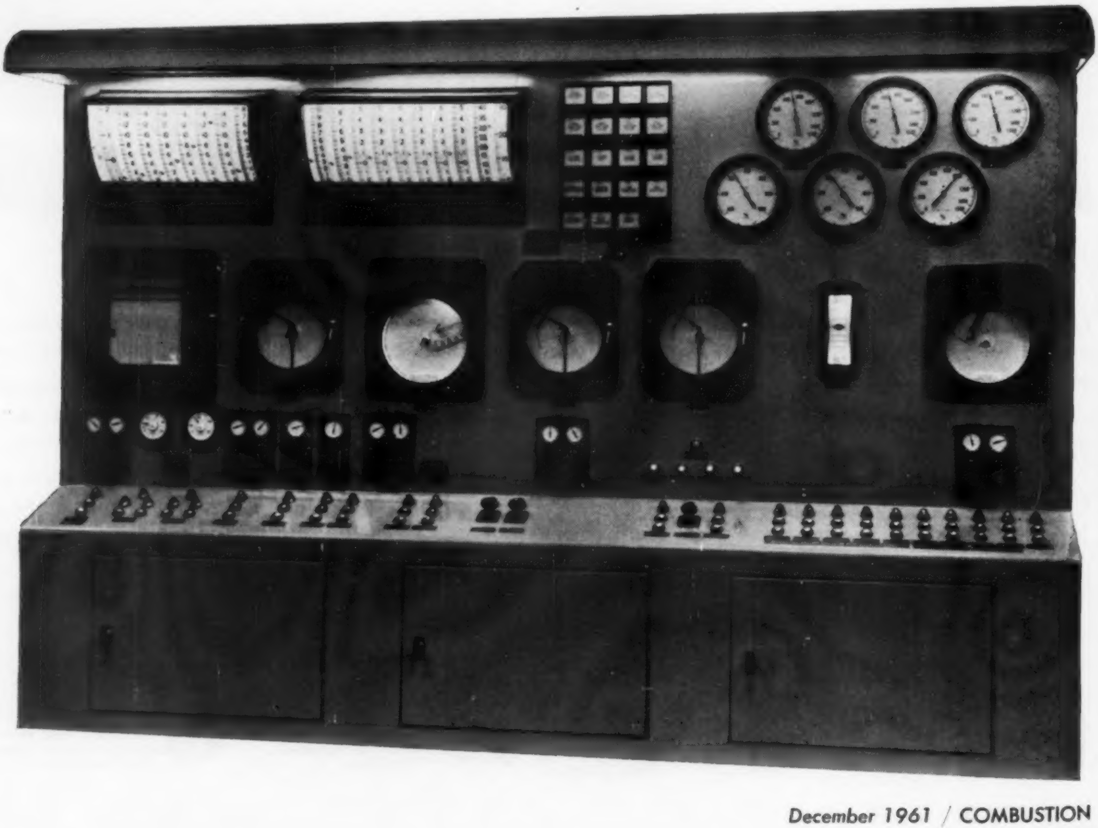
Copes-Vulcan combustion control has given high operating efficiency by close control of excess air. It has minimized fuel-bed disturbances by keeping the flow of air through the bed at the lowest practical rate. It has handled intermittent flows of waste fuel without incident. It has required no manual adjustments for variations in fuel moisture or quality, or in kind of fuel.

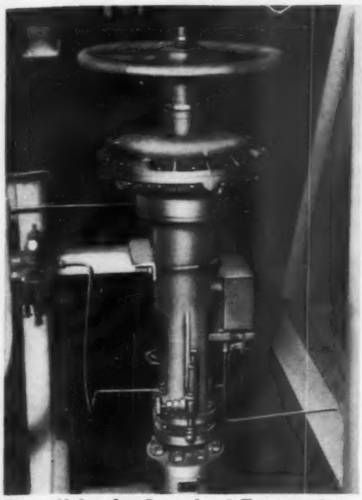
Copes-Vulcan three-influence feedwater control has maintained the proper drum level while feeding exactly as needed for steam output. Regardless of load conditions, Copes-Vulcan control has maintained final steam temperature at the desired 760 degrees F.

Why not read the complete story of this unusual installation as told in the new Bulletin No. 1078. Write for it today.

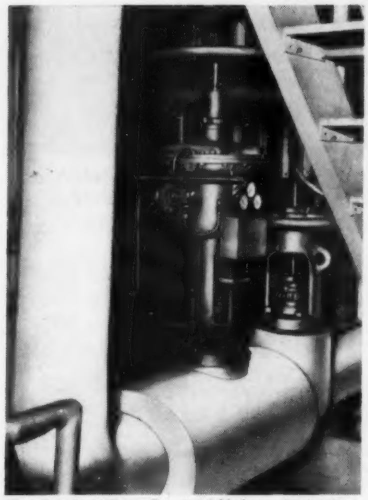
Copes-Vulcan Division, Erie 4, Pennsylvania.

Central Control Panel. All recorders and controls for the bark-and-coal-fired boiler are centralized on this Copes-Vulcan panel.

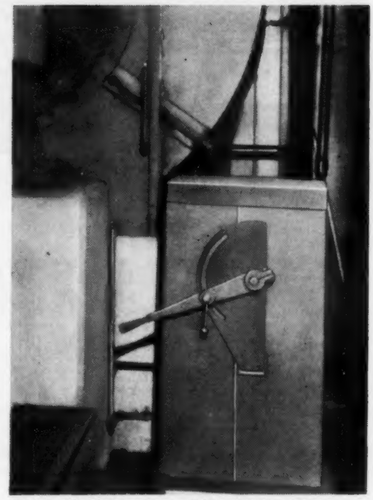




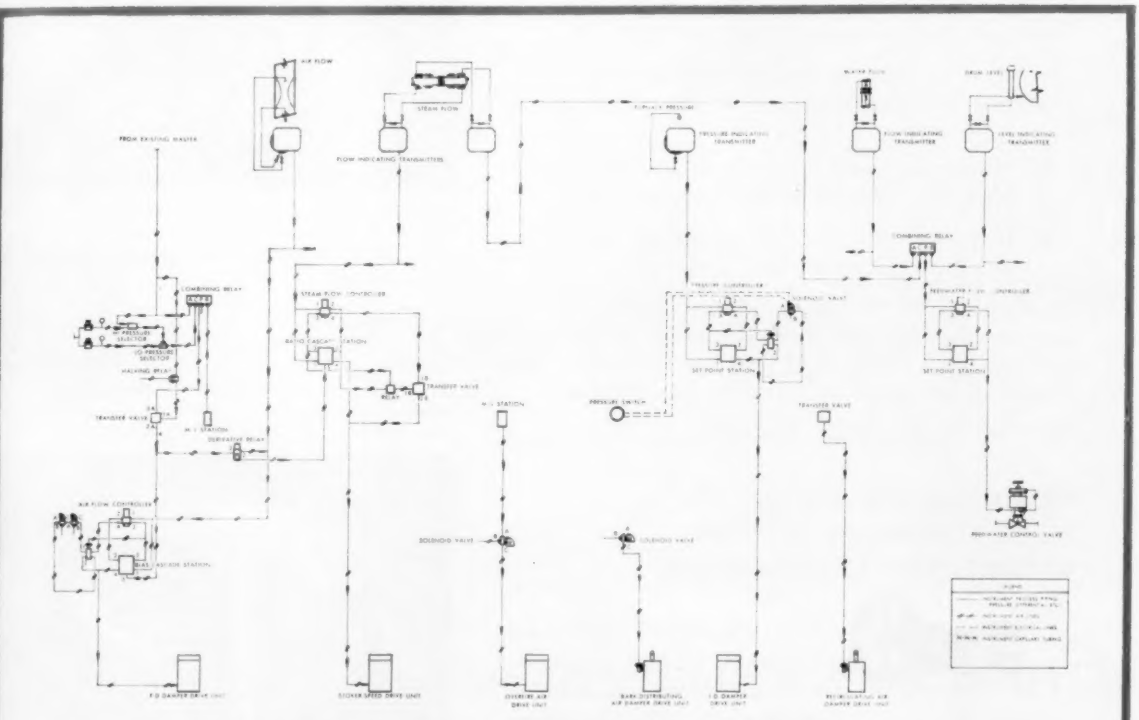
Spray Valve for Superheat Temperature Control. This Copes-Vulcan Type CV-D Spray Valve introduces cooling water into the superheater for dependably accurate steam-temperature control.



Feedwater-Flow Control Valve. This diaphragm-operated Type CV-D valve is part of the Copes-Vulcan three-influence feedwater control system



Drive Unit for Forced-Draft Fan Damper. This Copes-Vulcan drive unit, one of several in the control system, positions the forced-draft fan damper.



Schematic diagram of the Copes-Vulcan combustion and feed-water control systems on the bark-and-coal-fired boiler at Hammermill Paper Company.

Copes-Vulcan Division

BLAW-KNOX

BLAW-KNOX

Blaw-Knox designs and manufactures for America's growth industries: METALS: Rolling Mills • Steel Processing Lines • Rolls • Castings • Open Hearth Specialties • PROCESSING: Process Design, Engineering and Plant Construction Services • Process Equipment and Pressure Piping • CONSTRUCTION: Concrete and Bituminous Paving Machines • Concrete Batching Plants and Forms • Gratings • AEROSPACE: Fixed and Steerable Antennas • Radio Telescopes • Towers and Special Structures • POWER: Power Plant Specialties and Valves

YARWAY news briefs

from **Yarnall-Waring Company,** *Philadelphia 18, Pa.*

BRANCH OFFICES IN 19 UNITED STATES CITIES • SALES REPRESENTATIVES THROUGHOUT THE WORLD

HOW YOU CAN SAVE MAINTENANCE...INCREASE OPERATIONAL TIME WITH YARWAY COLOR-PORT GAGES

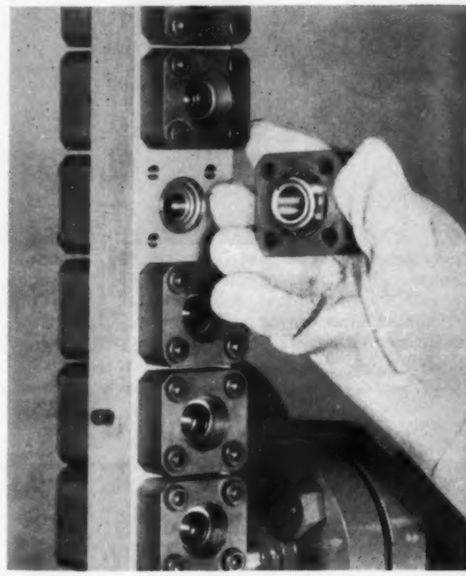
Two big problems confronting the operators of high pressure boilers—excessive maintenance and frequent downtime of water level gages—can be solved with new Yarway Color-Port Gages.

These Color-Port features will help you do the job:

- Patented spring loading of individual port covers, maintains proper pressure on glasses and gaskets at all times.
- Maintenance work can be done *with the gage in place.* NO TORQUE WRENCHES NEEDED!
- Individual "package" port assemblies (glass-mica-gasket) can be replaced in a few minutes.

These benefits, PLUS brilliant two-color readings (water space shows green; steam space shows red), PLUS Yarway quality—make COLOR-PORT your best gage buy! Available for all pressures from 0 to 3000 psi maximum.

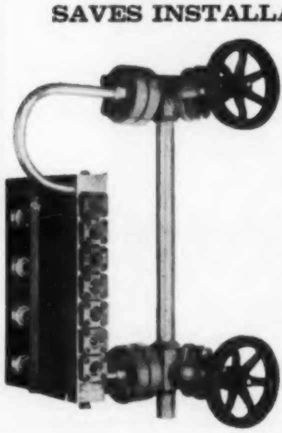
Write for Yarway Bulletin WG-1815.



Servicing the Yarway Color-Port Gage is simple! Just remove 4 cap screws (no need for torque wrench), place new "package" assembly in cover, and replace cover assembly. A matter of two or three minutes.

Yarway Color-Port Gage installed on boiler at Alan Wood Steel Co. Leading industrial plants all over the country as well as many major utilities are among the hundreds of satisfied Color-Port Gage users.

NEW COMPACT DESIGN WITH "WELBLOC" VALVES SAVES INSTALLATION SPACE



New "Welbloc" valves on Yarway Color-Port Gages reduce installation space requirements up to 40%. All working parts of valves are easily accessible. Improved direct flow from boiler drum to gage, reduces temperature differential.

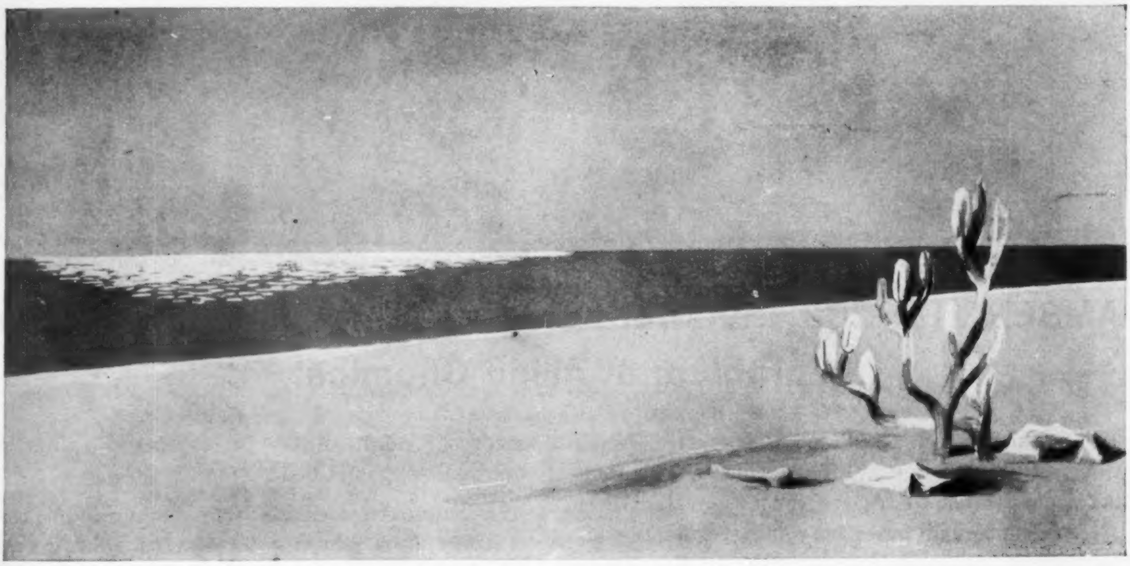
site for a town that drinks nothing but SEA

Sun-baked desert, parched and waterless — not a very promising site for a town. But, with the development of the Richardsons Westgarth multi-stage vacuum flash sea-water evaporator, it is now economically feasible for towns in arid coastal countries to draw all their fresh water from the sea.

These evaporators were pioneered in Great Britain by Richardsons Westgarth. The largest of them could distill 2,000,000 gallons of sea-water a day — enough for a town of 250,000 inhabitants — and the distillate is purer than many mains water supplies from conventional sources.

Richardsons Westgarth evaporators are at work in South America, the Middle East and elsewhere, providing fresh water for both domestic and industrial applications.

These units are at their most economical when used in conjunction with low-pressure steam or back-pressure turbines and, as manufacturers of most of the major equipment for power generation, Richardsons Westgarth are particularly well qualified to carry out completely integrated schemes.



RWG

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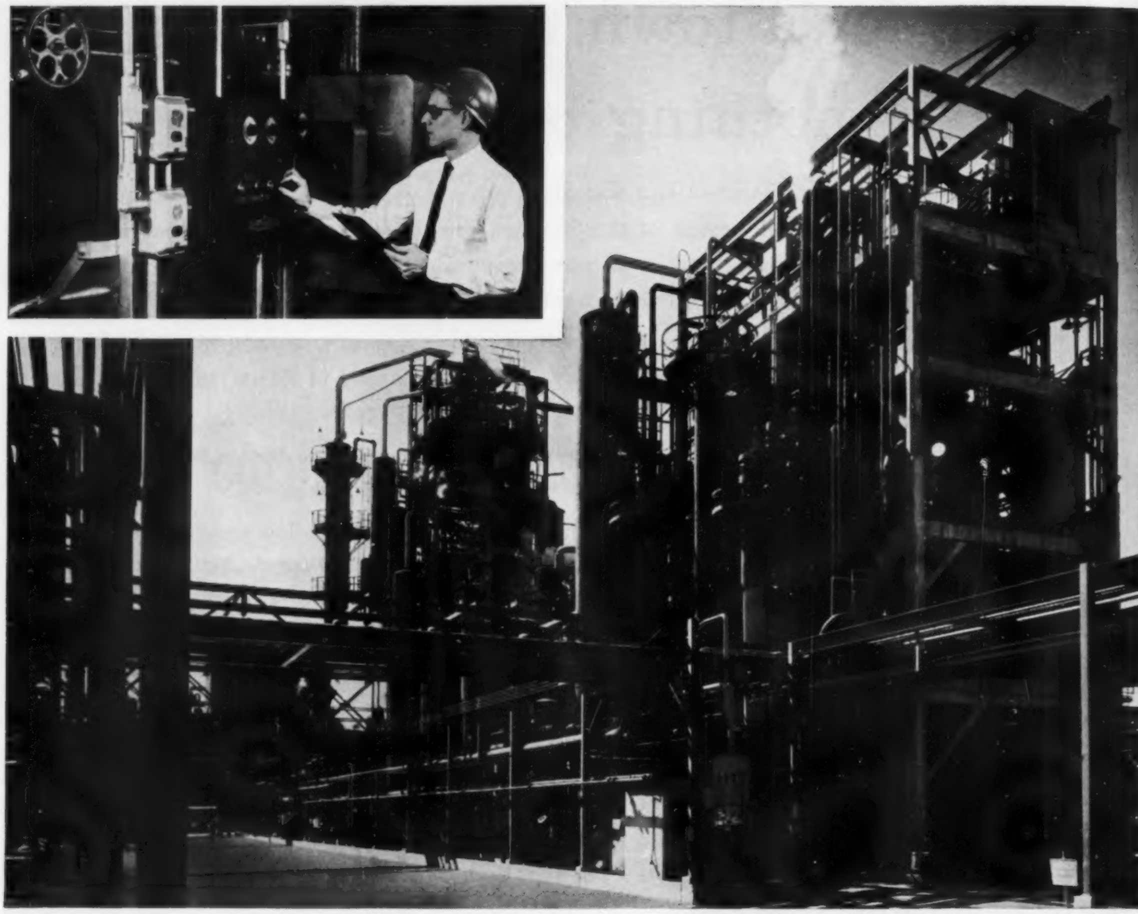


INSET: Control panel for softeners at Plastics Division, Allied Chemical Corp., Philadelphia

AMBERLITE® 200...answer to ion exchange resin breakdown problem at Allied Chemical

This is the problem the Plastics Division of Allied Chemical Corporation at Philadelphia has in softening boiler water for power generation: 1) Water supply—municipal water containing oxidants plus manganese, an oxidation catalyst. 2) Hot waste streams heat raw water to 60°-100°F.

These severe conditions produced this ion exchange history in 2 softeners: 1) First ion exchange resin used was a conventional high-capacity polystyrene cation resin. Relatively rapid decrosslinking made rebedding necessary in about 2 years. 2) Second charge—more highly crosslinked polystyrene resin used; sodium sulfite added to water to curb oxidants. Rate of decrosslinking slowed down; but after slightly more than 3 years, resin replacement was again necessary. 3) At that time, AMBERLITE 200 became commercially available. This resin was installed after thorough pilot-plant testing. To date, no decrosslinking is evident.

In resistance to oxidative decrosslinking and to bead cracking from physical stresses such as osmotic shock, AMBERLITE 200 is unmatched by any commercially available cation exchange resin.

Write for AMBERLITE 200 literature, and a brochure giving many other case histories of AMBERLITE 200 performance. Also ask for a 16-page booklet illustrating functions AMBERLITE ion exchange resins perform in power generating, chemical, electronic, and other industries.

ROHM & HAAS

PHILADELPHIA 5, PA.

Combustion

EDITORIAL

Is The Well Drying Up?

The predicted demand for graduating engineers for the 1961–1970 decade will average 81,000 for each of these years, according to the National Science Foundation. But the Engineering Manpower Commission of the Engineers Joint Council informs us that only 37,800 graduated into engineering in 1960. This was down from a 1950 total of 52,700. What is even more surprising and upsetting is that by 1965 EMC predicts the total of graduating engineers will drop still further to 32,000 based on present enrollment and retention rates. In other words, as the Commission sums it up: "The nation will have to make do with fewer engineering graduates for the next four to six years."

The Engineering Manpower Commission has very rightly interested itself in this problem. Their approach has been the formation of a Junior Engineering Technical Society, the JETS as they are called. This Society, as one of its principal functions, sees to it that qualified students are exposed to the career opportunities in engineering. Certainly this approach is a vital and perhaps a valuable one. We feel, however, that the traditional balance wheel of free enterprise—the law of supply and demand—should be working overtime. The normal stimulant is there—already the engineering graduate commands a premium of from $50 to $125 per month higher than his counterparts in liberal arts or business. Then why not the normal reaction?

It is our firm conviction that much of the reason for the well drying up, if it is, is the admission practices of our better-equipped colleges and universities. And engineering training with its needs for laboratories and demonstration aids, by and large, is taught at only the better-equipped schools.

University administration officers today demand high scholastic aptitudes, high standing in the graduating class (the top quarter is the usual cut-off point) and evidence of good preparation by a high level of specific courses often verified by College Board administered achievement tests. This is no mean accomplishment.

Any student who has the slightest qualms about meeting these admission requirements and yet wants a college education rules himself out as a potential engineer very early in his high school career. He has to. The competition he will meet in the chemistry, physics and advanced mathematics courses of the better secondary schools is of the highest order. And the curriculum must be designed to keep this cream of our secondary school student bodies sufficiently challenged. Out of this elite the nation is drawing all its scientists, many of its doctors and dentists and all of its engineers. The remaining fraction in this group are those who pursue in their college work other interests which do not require mastery of these subjects. It is from this fractional number that the JETS hope to find the recruits that will stem the tide.

But like most other things the picture is not completely black. The Pacific, the Mountain and the East South Central states reported gains from 3 to 6 per cent in engineering enrollments over the previous years. We feel the Manpower Commission would be doing a distinct national service if they established a study team on the admission practices, and on any and all other factors that could presumably influence enrollments so favorably as in these three fortunate areas.

COMBUSTION, in its continuing effort to report current thinking in the interesting and important area of furnace protection and automated firing, presents here two special articles. On this page Mr. Forney describes the designer's difficulties and on the opposite page Mr. Cowan reports on the purchaser's problem. Both authors have been active in systems design for years. We welcome them to the pages of COMBUSTION.

Burner Controls For Automatic Power Plants

By ROSS FORNEY

Forney Engineering Co.

Many of today's plants are quite large and represent multi-million dollar investments in the boilers alone. Striving for greater efficiency has pushed the parameters of control and instrumentation development to higher limits. Boiler operating requirements have exceeded the physical and mental capacities of the operators to such an extent that only through remote controls can they operate the boiler at all. The increased complexity of the larger units requires that more attention be paid to the automatic controls—and their limitations.

ONE of the factors contributing to increased efficiency in electrical generating stations is size. Million kw generators are now being designed, along with boilers which will deliver over 6 million pounds of steam per hour. Several innovations are now in service or are in the design or construction stage. There are super-critical boilers, and there are boilers designed for steam temperatures of 1050 to 1100 F.

Firing configurations vary considerably. Boilers are fired through the roof, from four corners, from four sides, with burners opposed, from the front only, from the rear only, and through the furnace wall tubes. Other special designs include "once through" boilers, forced circulation, and down-draft firing. In some units, steam pressure is controlled by the feedwater pump, and steam temperature is controlled by the burner.

Impending or existing emergencies can tax the operators' thinking and acting processes beyond their capacities. It is only through remote controls that the large boiler units of today can be operated at all. It is logical then, for power plant operators and designers to turn to the computer industry for assistance as the newer, larger, more complex boiler designs have developed. The first computers were designed to monitor, to log, and in some cases to alarm (annunciate). New computers, now going into service on large units, are designed to optimize the control settings, to provide start-off sequenced control, to report any pressures or temperatures which are out of range, and to shut down the plant in a predetermined sequence when necessary. Basically, these computers will act as super-operators, sending instructions to and receiving reports back from various "sub-loops" in the plant.

This report concerns itself with one of those "sub-loops": the burner control system.

The Present Picture

Automatic burner controls are installed and in service on the two of the major "computerized" central power stations now generating kilowatts. It is easy to look back and see some of the mistakes that were made. These errors serve to advance the art, however, and the lessons learned are being fed into new designs.

Considerable patience and tenacity has been exhibited by the field engineers responsible for putting these units into service. Much credit should be given these unsung heros; for them, "8 to 5" has no meaning. Some of the design errors were due to overlap on timing, but some were inherent in advancing from manually operated power stations to automatic ones.

The environment for one of these "computerized" installations is such that the boiler equipped with automatic burner controls is outdoors, near the ocean, with a salty sea breeze blowing through the plant most of the time. This particular boiler is fired from four *sides* at two elevations. There are a total of 24 burners. All burners are on gas, oil, or both. Natural gas is the fuel, or Bunker "C" fuel oil requiring pre-heating. The

(Please turn to page 23)

The editors of COMBUSTION found Mr. Cowan's report stimulating, challenging, even provocative. Following traditional editorial policy we present the author's story as received and will be happy to give space here to those who will certainly agree with him and to those who will just as certainly disagree.

Furnace Protection—Caveat Emptor

By F. COWAN

Compact Controls Co. Inc.

THE furnace explosion problem increases in intensity as boilers become larger and more expensive. Many ways of easing the problem have been offered. Some are helpful, some unrealistic for today's problem. The most important angle—the participation and responsibility of the purchaser—has not yet been investigated. A basic analysis of the situation from this viewpoint develops some interesting points.

A large utility steam generator suffers a furnace explosion. Hundreds of megawatts are lost to the system for months and millions of dollars are spent for repairs. In Illinois a furnace explosion destroys the only steam generator in an industrial plant. Total plant production is lost for weeks and thousands spent for repairs on a panic basis. In California an industrial boiler undergoes three furnace explosions in one year. Across the nation lives are lost and countless millions of dollars wasted in lost production, repairs and rising insurance costs—and still the devastation goes on.

It is less than amazing that under these conditions a boiler company executive can ask, "Why do we seem to have more furnace explosions now when most units have flame safeguards?"—and fail to get an answer. It may also come as a shock that another boiler manufacturer has pointed out in recent meetings that "More than 80 per cent of the explosions studied occurred on units with flame safeguard devices installed."

Details Are Revealing

When we begin to look into details we are in for an even greater shock. In one case where a flame safeguard device was advertised as absolutely fail-safe, it was found that the device continued to indicate flame in the furnace even after the flame sensing element was removed from the circuit! Should this device have been advertised and certified as "fail-safe" without a thorough environmental test? I think not. This problem was not artificially created but came about under actual operating conditions.

In the Midwest a package water tube boiler suffered near total destruction of the furnace envelope in a gas explosion even though it was protected with an approved flame safeguard. Gas supply was momentarily interrupted and when flow was re-established—before the slow acting safety device could trip the fuel stop valve—explosive ignition was triggered by hot refractory. The pilot had been turned off as soon as the main flame was lit in the approved sequence of operation. Three salient points are made here:

1. So great was the confidence in the flame safeguard device no one bothered to install a fuel trip interlock on gas supply pressure.
2. The slow action of the safety device was accepted without question.
3. Worst of all the pilot was turned off once the main flame was established. Had it been left burning the explosion could not have happened.

Let me anticipate here the reader's objection. He may be thinking, "But under high air flow conditions the pilot might not have ignited the main burner anyway." It must be said in reply that a pilot or ignitor is not worthy of the name if it can not reliably ignite the burner every time under any and all combinations of air and fuel flow. There are good reasons to believe turning off the pilot is the key to understanding the entire furnace protection situation. There was no need for it since gas was the main fuel and hence abundantly available. It was turned off for two reasons.

1. The scanner couldn't tell whether it was "seeing" the pilot flame or the main flame so the pilot

flame had been eliminated in the interests of main flame supervision.

2. The sequence, including turning off the pilot, had been approved by the underwriters groups and was therefore accepted.

We can begin to see at this point that this unhappy situation could never have developed had not the purchasers and users of this equipment exhibited some of the less admirable characteristics of sheep. So long as we allow ourselves to be pulled and tugged at the whim of so-called "accepted" sequences or specifications, so long as we permit vendors to ignore our question "Why?"—that long will we have to suffer with inadequate, dangerous furnace safeguard systems. There is one added responsibility and that is to let safety precede price. Once it is decided intelligently that a device or system is actually required and is right for a special need there should be no haggling over a few dollars.

It is essential to realize that a cheap system is often worse than no protection system at all. When the system is installed the operator is trained in a set routine. His responses to warning signals atrophy through lack of use and, to make things worse, emergencies arise in new and peculiar shapes as his new protective system disintegrates. It will seldom break down the same way twice and in short order the unit is plagued by frequent outages and can very well be more hazardous to operate than before controls were installed.

A "cheap" system can be almost as dangerous as a poorly designed one—and the cheap jobs are frequently bypassed entirely because the many outages simply cannot be tolerated.

What to Do?

So far the picture is grim and may indeed seem hopeless. What then, can you, the purchaser, do about it? That we must have safe, continuous operation is obvious. As boilers become larger and more expensive so do accidents become more costly and the dollar losses of curtailed production become more painful. Something clearly must be done to protect the purchaser or user of furnace protective systems. The answer is hard but simple—you must protect yourself.

Step 1. To lapse into the vernacular is to "shake the sheep habit." Nothing should be taken for granted except the power of the purchasing dollar and the answers that power can produce.

Step 2. Next, take an active interest in the development of the safety system and face the fact that some real work must be done by you.

Step 3. Move over the "THINK" sign on your desk and add one that says "WHY?" Make sure it's plainly visible to vendors of systems and components. Don't accept answers like "Well, that's the way everyone does it," or "Because it's approved." Just point to your sign and insist on a reasonable answer.

Step 4. With these attitudes in mind the development of a logic diagram can begin. This is a diagram like Fig. 1 that spells out each step in the sequence of operation in one-syllable words. No magic symbols are needed and even the Chairman of the Board should be able to understand it.

During step (4) the question "why" must be asked—and answered realistically—many times. Starting with

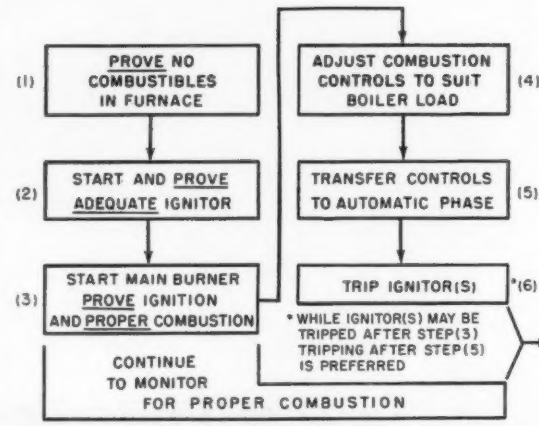


Fig. 1 Basic logic diagram applies to any system, any fuel, any burner. Actually performing steps in each box will require many added functions

the purge for instance, one might ask at the outset, "Why purge now—should something else be done first?" The answer will come back, "Yes indeed. It does no good to purge while fuel is flowing into the furnace. Let's prove that all fuel flow is shut off before we purge."

Following this procedure, the question must be asked, "Why turn off the pilot when the main burner has been lit?" If you're using a bottled gas pilot fuel the answer "Economics" will probably justify turning the pilot off. But at least you won't be eliminating a support for the main flame just to give a scanner a chance to "see" the main flame.

In a continuing process then, the logic diagram is built, and the question "Why" should be asked at every step. "Why two fuel trip valves in series?," for instance. Why not one good valve? Why can't the valve manufacturers furnish a valve to do the job? Why, if one valve is so prone to fail can't both of them fail together during normal operation? How frequently should they be checked?" "Every month" you say? Why not every week? Every day?

And on and on go the questions. "Why should I purge for 30 seconds? Why not 3 minutes, 5 minutes, 10 minutes? Why should I have an adjustable purge? Any mechanic, with one turn of a screwdriver can cause damage in the thousands or millions and maybe cost lives. Why can't I know what's right before I buy?"

You may have innocently acquired a "helpful" sample specification that advises alarm and indication of flame failure. Flame failure only? You want indication of the cause of every fuel trip or shutdown. Each safe trip should be treated as though it were a major catastrophe (it well might have been), and immediate steps should be taken to rectify the trouble. And *never* should a unit be started up without knowing why it shut down. This means at least a simple annunciator and annunciators cost money. So do explosions—an awful lot more money.

The sample spec may recommend a 15 second trial-for-ignition period. Why? Maybe you don't want fuel pouring unchecked into your furnace for 15 seconds. Maybe you think a good burner should light off in 5 seconds (so do I). Well, you certainly don't have to settle for a hazard you don't need, but you will if you don't ask why. Another oddity of the typical spec for indus-

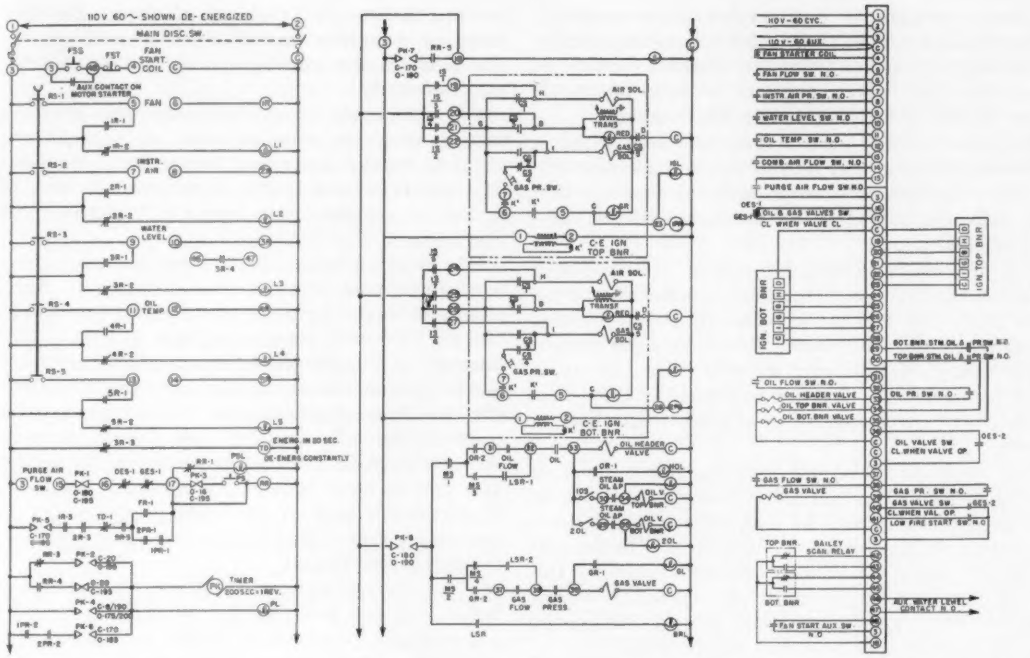


Fig. 2 The complexity of the elementary and field wiring diagram shown above illustrates the need for care and experience in developing practical physical arrangements from logic diagrams

trial units is the post-purge. After flame failure the forced draft fan is required to run a specified time before shutdown. Now its true the furnace must be purged but the time to do it is *not* when it's filled with a fuel saturated atmosphere and hot enough to ignite when supplied with air. The post-purge was originally conceived to supply air for combustion of fuel remaining in rotary cup burners after fuel valve closure and has no place with other type burners.

The list is long and the problem is complex (I said work would be required) but there's no call to be discouraged. The problem must be tackled one step at a time and each step is understandable to the average layman. If your vendor or advisor can't give a logical or reasonable explanation to your "why?" don't hesitate to enlist some one else's aid. Remember it's lives and dollars you're concerned with. Just keep on with your system approach and when your logic diagram is complete, check it for interference. It's possible to be so safe that the thing can't be started, you know.

At this stage some one with experience in designing and assembling furnace protective systems can help you avoid these interference pitfalls and at the same time translate your logic diagram into a wiring drawing such as shown in Fig. 2 that may be used to request quotations.

Make no mistake, the process is long and requires painstaking effort but the result is well worth while. And next time some one says, "You just can't get a good reliable furnace safeguard system," you can reply with an inner smile, "Why?"

BURNER CONTROLS

(Continued from page 20)

burner control system is designed to receive commands from a computer. The burners can also be controlled from the control room, or from a local control station at the burner front. The system is capable of supervising the burner during its lighting operation on either fuel, shifting from one fuel to another, and cleaning the oil burner after oil has been shut off.

Another computerized plant is located in the Gulf coast area. The boiler supplies steam for a 225 mw generator. This boiler is a pressurized, reheat boiler, with 18 burners on one elevation, arranged for front and rear firing. The burners are tilted downward from the horizontal, and fire opposed into a common furnace. Natural gas is the primary fuel for which the burner controls are responsible. Oil is a stand-by fuel, and when fired, is manually controlled.

General

There are two major areas of interest in the design of a burner control system for an automatic power plant. They have to do with the psychological problems inherent in the operation of a large utility type boiler and the physical, electromechanical obstacles standing in the way of automation. For the most part, these problems are not insurmountable. It does help to be aware of them during the design stage. These problems are not necessarily restricted to "automatic power plant design" alone. They are common to any boiler-burner combination where an attempt is made to remove some of the functions from the hands of human operators.

When a required function is "automated," the designer must replace the operators: (*a*) sensing—ability to see, hear, feel, and smell, (*b*) logic—ability to add and sub-

tract facts, compare to past experience or memory, draw conclusions, and to make a decision to take action, delay action, or take no action, (*c*) muscles—ability to open or close fuel valves, registers, or light pilots, (*d*) training—ability to do things in the right sequence.

Replacement of only part of these functions within a burner control system may lead to very serious complications. It is the opinion of some engineers that it is best not to automate any of these functions without automating all of them.

One of the major philosophies which has motivated engineers in the direction of automation is based upon the premise that boilers must be protected from operating errors under certain conditions. Ninety-nine times out of 100, the operators will react in such a manner as to prevent an accident. We are concerned mainly here with the small percentage of emergencies that lead to accidents.

Under most circumstances, the judgment level of operating personnel is normal. This is the level at which an operator would be expected to demonstrate his operating skill in routine circumstances. In the past most power plants have been designed assuming this judgment level remains relatively constant during periods of crisis, or that pre-instruction for emergencies will result in automatically correct human action.

Unfortunately, this is not the case with most people. In fact, most of us are subject to "panic" during a severe crisis. It is a matter of degree. The judgment level becomes an inverse function of the degree of crisis. In some cases, operating personnel have become immobile during a crisis, even to the point of not being able to carry out a simple function, such as answering a telephone. The safety of a multi-million dollar boiler cannot be best cared for in the hands of an operator at such time. It boils itself down to this: a large boiler must be protected from operating errors during an emergency.

Once a decision is made to protect the boiler during emergencies, it becomes apparent that the same protective equipment can be used for normal operation. Burners can be cut in and out of service, for example. There has been much discussion among engineers on where to draw the line of demarcation between computer control and the sub-loop system which operates the burners. Present designs call for a separate and independent sub-loop for burner controls. This permits operation of the burners from the firing aisle, from the control room, or from the computer. To our knowledge it has not occurred, but it is presumed possible for the computer to abdicate its responsibilities, or to issue a catastrophic signal. Like a good soldier, the burner control system should be designed to reject illegal orders. This subject must be explored thoroughly in each design.

Recognizing and exploring all of the contingencies associated with a power plant emergency requires a great deal of time at the conference table, and many operating contingencies can be recognized only during the development of the plant design itself. This is a continuing process, during the design stage, and flexibility must be built into the burner control and computer design so that modifications in the plant design can be accommodated in the control system. The heart of the burner control system is the flame detection system. Because of the number of burners and variations in configurations on a modern boiler, the problem of flame discrimination becomes somewhat complex. The problem is compounded by the possibilities of burning several fuels simultaneously.

On eight of the present ten automatic central power stations under construction today, it is the intent of the client to provide individual burner flame discrimination. The burner control system is designed to shut off fuel and air to any particular burner if its detector indicates "no flame."

The designer must consider several special problems when individual discrimination is required. The quantities and wave lengths of light generated by the burning fuel are influenced considerably by: 1. Type of fuel being burned. 2. Turbulence in the immediate throat area. 3. Ratio of primary and secondary air to fuel. In addition to this, the physical arrangement of the furnace will make a considerable difference in how "discriminating" the detector must be. Each furnace design, burner location, and arrangement must be considered very carefully. If this is not worked out early in the design, then it becomes a very difficult problem to cope with after the boiler is in operation.

After the burner control system is installed on the boiler and put into service, we learn how intelligent our designers have been in making the equipment easy to maintain. Maintenance personnel are subject to the same human frailties that all of us are. It is necessary to take these human frailties into consideration when designing an automatic burner control system. Some of these are:

1. The burner front piping and wiring conduit arrangement must be as neat and inconspicuous as possible. This has a definite psychological influence on the operators, as well as maintenance personnel. Experience has shown that a congested burner front creates an impression of complexity. If, in the minds of the plant people, this is a complicated system, then you may rest assured they will have difficulty operating and maintaining it. On the other hand, a system which appears neat and simple to operate, will establish a more tolerant attitude on the part of the operating and maintenance personnel when the inevitable malfunctions show up.
2. As the responsibilities of the computer and burner control systems are expanded to carry out more complex functions, the circuitry also becomes more complicated. This makes the job of trouble shooting more difficult. For start-up purposes and for maintenance, a series of sequence lights is added to pinpoint the difficulty.
3. In most cases, maintenance personnel will service the equipment which is simplest to maintain. If they never get around to properly servicing the burner controls, it may be the fault of the design engineer.

In addition to the human factors involved in the design of a burner control system, there are a number of physical and electro-mechanical obstacles to be overcome. Some of the more important considerations are:

1. Ambient conditions have an overwhelming influence on the design of an automatic burner control system. The elements of this system are required to function under conditions of high temperatures, soot, vibration, ash, blowing sand, salt spray, and last,

but by no means least, the abuses of the painters.

2. One of the most difficult tasks of designing a burner control system is selecting reliable hardware to carry out the control functions. This does not mean the designer should necessarily purchase the most expensive equipment. Quite often the price of some equipment can be misleading as to the quality, in either direction. A design engineer's lack of field experience may contribute to improper selections. It is not uncommon for an equipment salesman to be so "in love" with his product, that he cannot see its weakness in specific applications. For this reason, there is no substitute for actual field experience with the specific hardware in an identical application.

3. On one automatic boiler, there are approximately 9000 sets of electrical contacts in the burner control system alone. These contacts may be in the form of relays, position switches, pressure switches, or manual switches. This in itself can spell trouble unless the engineer takes special note of:

a. *Electrical contact design.* When the contacts open, and an arc is struck, the rate of heat dissipation is determined by the mass of metal in the contact itself. The more rapidly this heat is dissipated, the less the contact is damaged. For this reason, a large safety factor is required to insure contacts of sufficient size.

b. *The cabinet* within which the contacts will be housed. A weatherproof cabinet with a conduit entering at the top negates the water tightness. Water will condense in this conduit due to breathing. This, in turn, may rain down on the relays inside the cabinet.

c. *Position switch mounts, and actuators.* One of the greatest areas of neglect in the design of a system such as this is the reliability of the position switch. This switch must be housed in a weather-tight container. It must be capable of accepting considerable overtravel during actuation. The actuating cams and levers should be easily adjustable and, above all, they should be capable of accurate adjustment. On this application, an actuating cam of less than 3 inches in diameter is very difficult to set. The internal electrical contacts must have positive spring force for separation. The "cricket" or "light touch" action employed on some position switches is not satisfactory for boiler front application.

4. *Weather protection* for personnel and electrical equipment during maintenance. All electrical control systems inevitably need maintenance. This can be during a snow, rain, or dust storm. During this time, both the maintenance personnel and electrical equipment, need protection. It is highly desirable to protect the control system inside of a closed "walk-in" type of burner control center. This makes an ideal location for relays, and with the addition of air conditioning, the problems associated with moist salt air can be eliminated.

5. *Circuitry design which is self-checking and self-corrective.* It is not uncommon for a burner control system to be required to function properly after sitting idle for many months. During this time of idleness, electrical contacts may have become corroded, electronic equipment become inoperative, etc. For this reason, it is desirable for the system to initiate an internal check. This will verify that the components function properly and will protect the boiler if called upon to do so.

6. A constant power supply is desirable for use with the burner control system. However, it is seldom available. The burner control system should be capable of functioning without nuisance shutdowns during voltage dips and interruption.

7. Selection and arrangement of the burner fuel valves must be a major consideration in the design of an automatic burner control system. The three major considerations in selecting fuel valves for an automatic burner control system are:

a. *Tight close-off.* It is necessary to insure the burner fuel valve can be completely closed off within the power limits of the actuator. The valve plug and seat should be self-cleaning as the plug moves into place. If the valve plug can be prevented from seating properly due to welding rod, pipe scale, etc., this valve should not be used in the burner fuel valve application.

b. *Application of position switches.* Any position switch placed on a valve to determine when it is in a closed position should be able to recognize the difference between "almost closed" and closed. The lubricated plug valve provides from 40 to 50 degrees of rotation after fuel flow shut off before the position switch is actuated. This overtravel removes any doubt about the accuracy of the position switch feedback signal.

Eight of the automatic central power station type boilers now in service or design employ a *rotating type plug valve* for the burner fuel valves.

c. *Correct philosophy.* In most valve-actuator designs, there is some kind of coupling between the valve plug and the actuator. It is always possible this coupling can work itself loose, or break. For this reason, it is logical for the position switches to be mounted on the "driven" rather than the "driver." Feedback signals as to the position of the actuator are of little consequence to the burner control system; the required information pertains to the position of the valve itself.

Conclusions

The previous paragraph just skims the surface on valve selection. Every item of hardware and its application must be engineered in depth.

The ability of the computer to function usefully depends entirely upon its connected input device.

One of the functions of a computer is to provide more information to the operator, to "think" faster than the operator, and to take pre-planned action during emergencies. The greatest hazards to the boiler occur during start-up or during low load operation, when all burners are not in service, or a stable fire is not established. Individual burner controls, with each burner operating as a unit, are desirable.

Experience shows that the burner control system "subloop" is needed the first time the boiler is fired.

It provides a useful operating and safety function while the plant is going through the trial operation phase. Automatic burner controls are helping to bridge the gap between manual and automatic power plants.

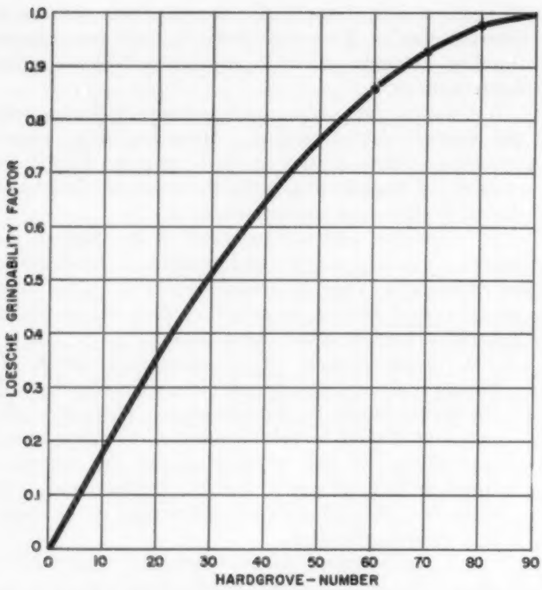


Fig. 1.—Relationship between Loesche Grindability Factor and Hardgrove. *abscissa:* **Hardgrove number;** *ordinate:* **Loesche grindability factor**

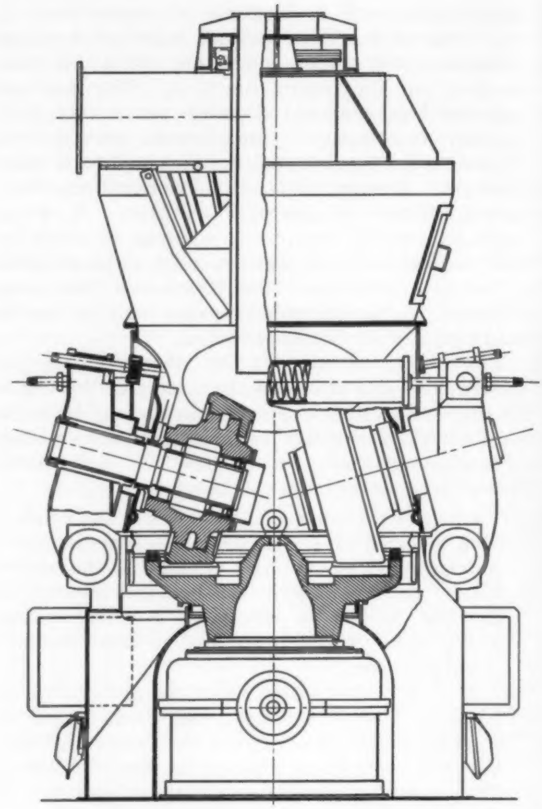


Fig. 2.—Loesche roller mill

Roller Mills.—A Contribution To The Assessment And Selection Of Coal Pulverizing Mills*

By W. SCHÖNING

The calculation of the output and power of a mill required for an unknown coal is one of the most difficult tasks of a project engineer. It appears necessary to stress these difficulties standing in the way of an exact solution of this task.

UNFORTUNATELY, there is no reliable criterion for the grindability of a coal which is equally valid for all pulverizing systems.

During the actual pulverizing process the only useful expenditure of work is the destruction of the cohesion of the feed material. The mill accomplishing only the separation of the coal particles from each other to the prescribed size with the exclusion of all undesirable other work would be the ideal comminution machine. The comminution process itself requires theoretically only a small amount of work. Unfortunately there does

* Published with the permission of the Association of Power Boiler Owners E. V., Essen, Germany, from their publication *Mitt. V.G.B.*, No. 71, 1961, (April) 123–7.

not exist in the field of comminuting hard materials a machine with a purely cleaving action. The comminution process in all existing machines is very complicated. Comminution proceeds via pressure, beating, pushing, bending, friction, acceleration and movement.

Comminution does not take place only by the effect of the milling bodies on the feed but also by the mutual influence of the particles on each other. This causes considerable losses by the generation of heat, plastic and elastic deformation and idle running losses in the comminution mechanism.

Coal Grindability

Since the various types of mills with their milling mechanism proceed along devious paths to approach as closely as possible the ideal comminution process it is impossible to predetermine the grindability of a coal, in the author's opinion, held with a general valid apparatus for all the different fine grinding machines. (*See Editor's Note, p. 29*)

The mill designer has suitable means to determine the grindability valid for his particular machine. These are laboratory machines with which the specific grinding resistance can be determined if in a certain case a coal sample is available. These laboratory mills are small machines which are supposed to accomplish the grinding of the feed in the same way as the production mills.

The values determined in these test mills differ frequently from those actually obtained in the production mills so that the mill designer has to apply correction factors based on years of experience with many different feed materials and resulting from the relation between test and operational values.

Attempts have been made to design an apparatus supplying an indication of grindability for all mills. One of these is the Hardgrove mill designed in America. This is based on Rittinger's law by which the comminution work required is related to the increased surface obtained by comminution.

A coal sample ground in a miniature mill is subjected to a certain amount of grinding energy and the new surface generated, i.e., the particle size distribution, is determined by screening.

Hardgrove started with his method from the fact that it is necessary, in order to obtain an acceptable standard of grindability, to use always the same lump size of the coal sample, the same number of revolutions of the test mill and the same method of screening.

The mill producers have also attempted to find agreement between the grindability factors determined by the Hardgrove apparatus and those found by their own laboratory mills to obtain, for international correspondence and export orders, a valid means of agreement on grindability for the calculation of output and power required.

One Manufacturer's Attempt

Such a relation between Hardgrove factors and those determined by Messrs. Loesche K.G. is the curve shown in Fig. 1. It must be remarked, though, that the Hardgrove values scatter so much with respect to the empirical grindability curve that when using Hardgrove numbers considerable safety factors have to be applied.

The Loesche mill (Fig. 2) is a sprung roller mill consisting of a revolving grinding table the number of revolutions varying with size from 40 to 90 rpm on which two large conical grinding rollers run. The axes of the rollers are fixed to pivoting levers connected by strong springs to each other so that the rollers are pressed elastically on to the completely horizontal grinding table. The springs should press the rollers on to the table with the force most suitable for the coal being ground. To this end the pretensioning of the springs is adjustable. The springing must be so elastic that the rollers can move upward and downward depending on the thickness of the feed on the table. The arrangement of the springs is so designed that the force exerted on the two rollers of the Loesche mill is as uniform as possible.

In large mills of this design with their rollers of ever increasing weight the steel springs have been replaced by an hydraulic-pneumatic spring mechanism. This has the advantage that the grinding pressure can easily be altered during operation and the hydraulic mechanism can also be used for lifting the rollers from the table during repairs.

The classifier placed on top of the mill housing was for many years a rotating screening basket with slotted blades but in recent years a design originating from America using classifier blades is applied.

A main point of a good pulverizer is rapid classification during pulverizing, i.e., to free the pulverizer as rapidly as possible of the material ground to sufficient fineness. To this end good cooperation between mill and classifier on the one hand and a classifier of high efficiency on the other is of great importance. The more efficient the

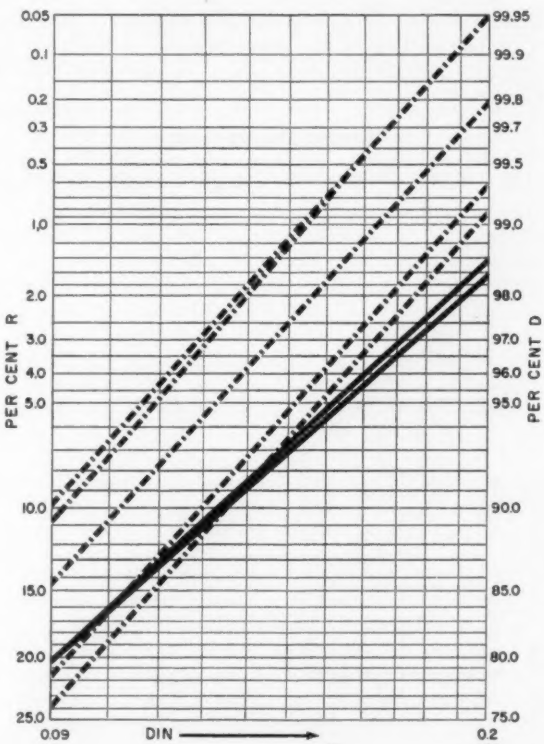


Fig. 3. Pulverized coal particle size distribution curves: ——— Loesche sieve basket classifier; —.—.—.— Loesche blade classifier

classifying process the less the recirculation of the material between mill and classifier; the higher the classifier efficiency the quicker is the material removed from the mill.

The Loesche-Hardinge Classifier

The high classifying efficiency of the Loesche-Hardinge classifier effects a steep particle size distribution curve (Fig. 3), so that for the finenesses usual for pulverized coal firing the new classifier produces only traces of residues on the DIN (Deutsche Industienorm, German Industrial Standard), sieve 0.2 which is of advantage for complete combustion.

The number of revolutions of the classifier can be remotely controlled and thus the fineness be easily adjusted during operation and it has a lower air resistance than stationary classifiers. In addition by the sudden change of number of revolution a sudden change of coal feed into the furnace can be obtained.

Of great importance for a good and uniform combustion of the pulverized coal produced in the mills is the uniform distribution of the ground material, such as it leaves the mill, to the individual burners. From the present-day large mills the pulverized coal is distributed from one mill to four, eight and even more burners. The distribution of the pulverized coal to each burner should be as uniform as possible quantitatively at the same coal-air ratio.

The Loesche K.G. use different distributor designs (Fig. 4) depending on the type of mill, i.e., pressure or suction mill. In both systems great attention is paid to low resistance in addition to good distribution.

The Loesche mill is used as injection mill both for direct injection and intermediary bunkering and also in central milling plants where because of the large individual outputs the low power requirements are of advantage.

Central Milling Plants

In central milling plants (Fig. 5, No. 1) the pulverized material is passed to a cyclone in which it is separated from the carrier air. The air leaving the cyclone and containing only very little fine material is freed of the residual fine dust in fine filters (fabric or electrostatic filters).

A central milling plant is used even today where for example pulverized coal is required simultaneously at various firing points widely separated from each other such as in metallurgical works. This is the case where there is added a blast furnace slag cement works with a rotating furnace fired by pulverized coal and pulverized coal fired boilers.

The intermediary bunker plant (Fig. 5, Nos. 2 and 3) installed in the boiler house in front of the boiler has a relatively small bunker for pulverized coal. It is used if in addition to coal other fuels not requiring pulverizing are available, e.g., if blast furnace gas must be fired as it becomes available and the addition of pulverized coal may vary between 0 and 100 per cent.

In cellulose works firing sulfite lye and waste wood in addition to coal intermediary bunkering is also often of advantage.

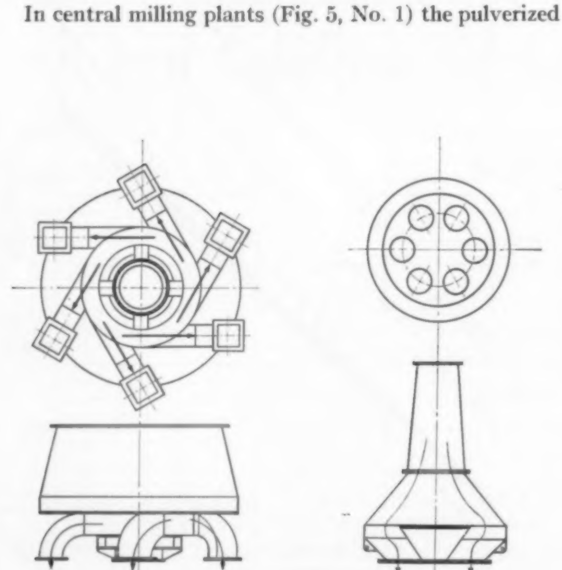


Fig. 4.—Pulverized coal distributor, ***left hand:*** **half-pressure mill;** ***right hand:*** **full pressure mill**

Mill Fans

The injection of the pulverized coal into the boiler can be done either by the mill fan or a special exhauster (Fig. 5, Nos. 2 and 3, respectively).

The direct injection mill (Fig. 6) injects the pulverized coal produced in the mill directly into the furnace by means of the mill fan and without intermediary bunkering. The scheme presented in Fig. 6, No. 4, uses a special exhauster behind the mill as is required for suction mills.

For pressure mills this fan is a hot air fan installed in front of the mill (Fig. 6, No. 5). In special cases there is no real mill fan and this replaced by a fresh air fan in front of the air preheater made possible by special arrangement of the air preheater circuits (Fig. 6, No. 6).

The comparatively small amount of coal in the mill makes it suitable for use as injection mill. The simultaneous and rapid change of coal feed, air volume and classifying makes it also adaptable to partial loads.

Since the Loesche mill operates as air flow mill it can be operated with mill drying, i.e., with drying of the coal within the mill. This drying action is so intensive because of the high degree of turbulence in the mill housing that at a low level above the table the carrier gas entering at temperatures of up to 1100 F, where the moisture content is high, is cooled to an exit temperature of 176 to 248 F. Initial moisture contents of up to 28 per cent are admissible.

The drying in the mill can be carried out with hot air from the preheater or with flue gas. Depending on application the mill is operated with suction, half-pressure or full pressure (Fig. 7).

When using flue gas for drying and intermediary bunkers the mill is operated as suction mill and the mill fan draws in the flue gases. The suction mill is also recommended for central milling plants.

When used as half-pressure mill the full pressure of the hot air is taken from the air preheater at the entry into the mill so that the exhauster following the mill requires less static pressure, becomes smaller and saves in wear and power. In the mill itself is the ± point which facilitates the sealing of the mill against the small positive or negative pressure (Fig. 7).

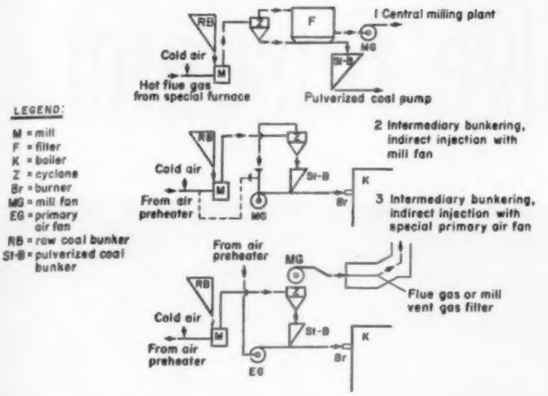


Fig. 5.—Circuit arrangements for Loesche mills, 1 central milling plant; 2 intermediary bunkering, indirect injection with mill fan; 3 intermediary bunkering, indirect injection with special primary air fan

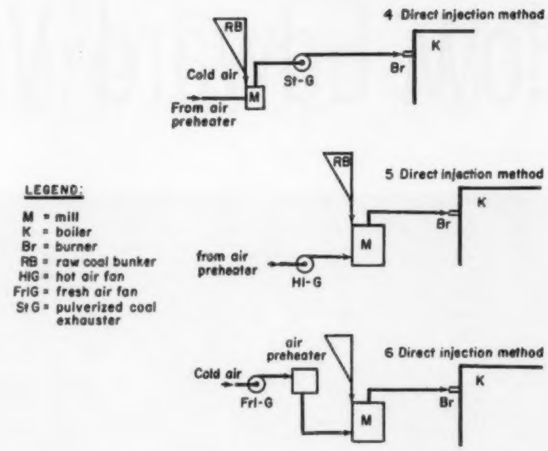


Fig. 6.—Circuit arrangements for Loesche mills, 4 direct injection method; 5 direct injection method; 6 direct injection method

The Loesche mill is made completely pressure-tight in all parts so that it can also be operated as full pressure mill. All rotating parts of the mill are provided with well proved slip-ring seals to which is added sealing air in pressure mills. The mechanical seals are used to reduce cold air addition to a minimum. The bearings of the rotating parts are provided with lip or simmering seals and also sealing air to prevent entry of dust.

Range of Application of the Loesche Mill

The range of application of the Loesche mill includes practically all bituminous coals. Young bituminous coals, bituminous coals, low-temperature brown coal briquettes and breeze can be pulverized economically.

The mill is available in various sizes for outputs from 1.6 to 80 t/h. The permissible lump size of the feed varies with mill size between 10 and 60 mm (0.39–2.36-in.).

Wear is small because of the long operating times of the few milling parts. It is found mainly on the surface of the grinding rollers and grinding table segments. They both reach 8000 to 12,000 operating hours when grinding normal Ruhr coals and are made of a hard manganese steel; when made of a specially developed electrically cast hard steel with special heat treatment they may reach 25,000 to 30,000 operating hours. By using special jigs the times required for replacing heavy mill parts of large mills because of wear are greatly reduced. The replaceable blades of the special exhauster for injection mills if used as half-pressure and not as full-pressure mills are made of cast steel of a Cr-Ni alloy and can operate for 3500 to 4500 hr on normal Ruhr coal. Since the impeller is arranged overhung the worn blades can be replaced very quickly.

The specific power consumption varies with size of mill and is between 10 and 14 kw/t pulverized coal for both mill and fan and is based on a fineness of grinding with a residue of 15 per cent on DIN sieve 0.09, 8 per cent initial moisture content and a grindability of 78 Hardgrove. When grinding to a fineness of 20 per cent residue and more the specific power consumption for mill and fan together is reduced to below 10 kw/t. Since the rollers do not touch the table during idle running due to special arrangements but are rotated only after start of the coal feed by the feed pushed beneath them its driving power required during starting is very low. Even with a full mill, e.g., after an interruption of the electric supply the drive motor, generally dimensioned for 25 per cent above the maximum power required, goes up very quickly to full numbers of revolutions. Squirrel cage motors are therefore generally used.

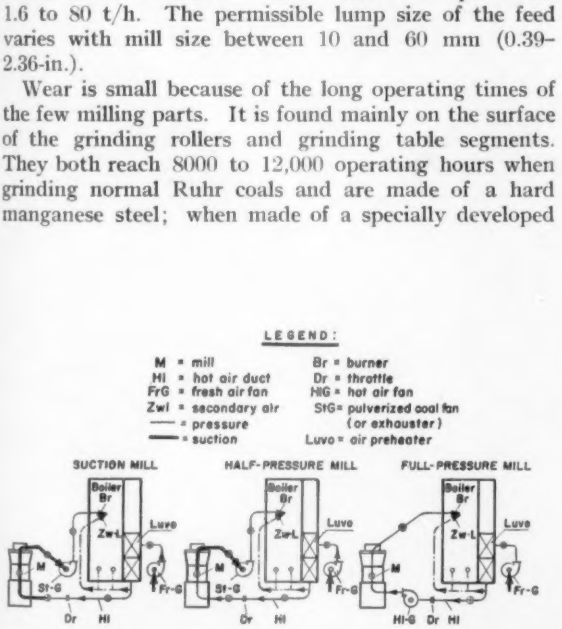


Fig. 7.—Pressure schemes for Loesche mills. —— suction; — — pressure

Editor's Note

As the author points out, in Germany the fuels available apparently employ empirical grindability curves that differ sharply from the accepted Hardgrove values, hence Figs. 1 and 3. All U.S.A. mill makers follow the Hardgrove numbers implicitly. So while the points the author makes are not necessarily directly applicable to U.S.A. practices the editor felt an exposure to the thinking of a mill designer would be beneficial.

How Edward Valve Research

Reduced Pressure Drop 70%

Power industry advances in unit size created a need for large, high pressure steel valves (ten inch size and larger, 1500 lb class and higher) with three basic qualities: 1. Permanent tight seating; 2. Capacity to handle high flow rates being encountered in new, high pressure plants; 3. Reduced downtime through simplified maintenance. Edward researchers developed the Flite-Flow* design to satisfy that need. This is their story.

In 1951 Edward had already developed large cast steel globe valves with excellent dependability and repairability. Long experience in building inclined stem Y-type valves in small sizes indicated that this configuration offered a more efficient flow path. Edward research engineers set out to learn whether sufficiently strong pressure containing structures might be built in the Y-type design in larger sizes. They also sought to find out if pressure drop could be reduced sufficiently to make such a valve practical for high pressure power plant services.

The project consisted of three steps:

1. INTERNAL CONTOUR DESIGN—Flow tests were conducted with a series of plastic models. Early in the testing program it was observed that flow capacity was not always directly related to the size of the opening. Reduction of turbulence proved to be even more important. This eventually led to subtle internal contour changes to pre-shape the flow before passing through the valve seat. More material was added to certain internal areas to gain additional structural strength.

2. DISK GUIDING TESTS—To compensate for the angular position of the stem-disk assembly tests were conducted to determine whether conventional three-point guiding used in vertical stem Edward valves would be adequate for the inclined stem design. Experiments suggested that four equally spaced guiding surfaces would be superior. This is important in floating disk types such as check or stop-check valves where disk-piston assembly must seat automatically.

*T.M. Reg. U.S. Pat. Off.

3. STRUCTURAL STRENGTH—The usual weakness of a Y-type pressure containing vessel received much attention. Optimum valve contour as determined by flow testing permitted use of a structural member in the flow passage at the downstream side of the seat port. This structural member provides strength exactly where needed without significant increase in pressure drop. Introduction of this segment to the valve body casting without sacrifice in pressure drop was a significant achievement.

RESULTS: This program covered a period of six years. Tests of the completed design were most gratifying. Structural stability, a major problem, was excellent. Strain gage and brittle lacquer tests of finished valve bodies showed stresses well within acceptable limits. Pressure drop reduction amounted to as much as 70 per cent from best previous globe valve experience. Extended tests of finished product at pressures and temperatures above rating showed no operating weaknesses. The Flite-Flow is truly a dependable, repairable, low pressure drop valve.

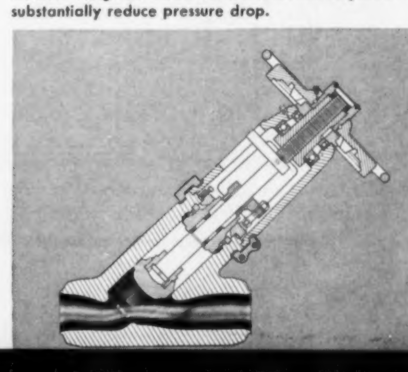
Edward builds a complete line of forged and cast steel valves from ¼" to 24" for industrial, marine, petroleum and technological services. For more detailed information, contact your Edward Representative, or write Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal.

EDWARD STEEL VALVES
another fine product by
ROCKWELL

◀ **W. G. Lunt,** research engineer, and **E. B. Pool,** chief research engineer, study flow phenomena in plastic half-model of tentative Flite-Flow design.

Edward research team lowers experimental valve into test furnace where it is subjected to prolonged extremes of heat and pressure. This was one of the final steps in the development of Flite-Flow valve design. ▼

Cutaway view of Flite-Flow valve showing how inclined stem Y-type valve configuration has been adapted to larger size units for power plant services. This internal contour design enabled Edward research engineers to substantially reduce pressure drop.



By IGOR J. KARASSIK*

Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—Part XXVI

QUESTION

When high speed boiler feed pumps are installed in an open feedwater cycle, they frequently require the use of a low speed booster pump. Since the possible interruption of electric power supply to the booster pump motors independently of the situation with the main pump drives presents some hazards, is it possible to connect the booster pump to the main pump drive?

ANSWER

Where the high speed pump is driven by an 1800 rpm electric motor through a step-up gear, it is possible to drive the booster pump from a shaft extension of the same motor on the opposite side. As a matter of fact, with the exception of a few installations where benefits could be obtained from locating the booster pumps at a lower level than the main feed pumps themselves, all the motor driven installations of high speed pumps that we have made are so arranged. A typical elevation of such a unit is shown on Fig. 1.

In the case of turbine driven boiler feed pumps, using a single driver for both main and booster pumps presents a choice between two possible arrangements:

a. A double shaft extension for the steam turbine, with a step-down gear for the booster pump. This is not a practical solution for steam turbines designed for boiler feed pump drives and would no doubt entail considerable

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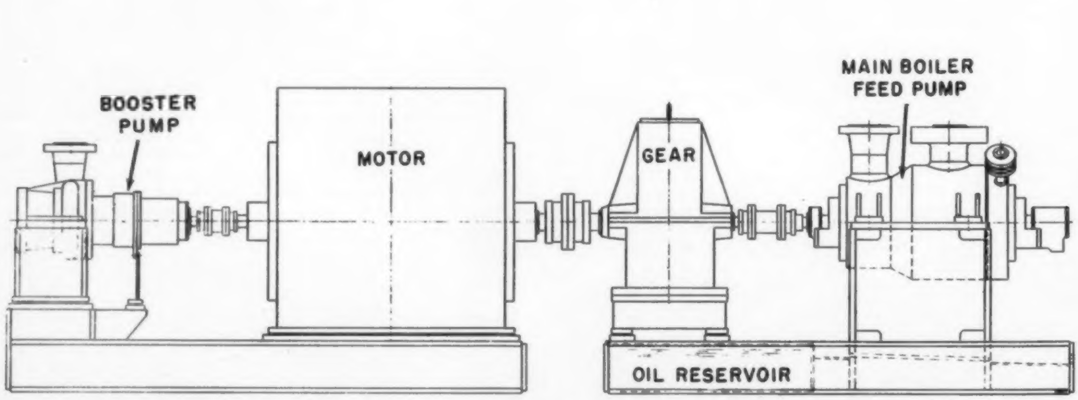


Fig. 1—The usual arrangement for the drive of a booster pump is to employ a shaft extension of the main feed pump drive.

expense that would be difficult to justify. (Incidentally, this is no longer true in the case of main shaft driven boiler feed pumps which can now be driven from the front end of the turbine.)

b. As an alternate, the main feed pump shaft could be extended through the thrust bearing and drive the booster pump through a step-down gear. This arrangement is not too satisfactory: both booster pump and gear would have to be removed whenever the main feed pump would require dismantling for inspection or overhaul; in addition this arrangement would not permit using the booster pump for start-up purposes. Normally the practice is to operate the motor driven booster pump to build up boiler pressure to 100 or 200 psi, which is normally more than sufficient to start the boiler feed pump turbine.

As to the hazards of a separate booster pump drive, they must be recognized but need not be a deterrent to the advantages that can be derived from installing a booster pump. If separate buses are used for the individual booster pump motors, some insurance is available against interruption of electric power. If the main feed pumps are capable of operating safely in a flashed condition, booster pump discharge pressure could be restored after a temporary interruption by switching to another source of power and no major difficulty should be encountered. Finally, if the main feed pump is driven at variable speed, it can generally be slowed down sufficiently so that the available NPSH without the booster permits the boiler feed pump to resume handling feedwater. This should be done manually and slowly. As soon as normal pumping is restored, the pump can be tripped out—assuming that it is not possible to restart booster pump delivery.

Question

In those installations where there is only one full capacity boiler feed pump—what is the usual practice for providing start-up supply of water?

Answer

If a closed feedwater cycle is used, the condensate pumps (sometimes supplemented by separate condensate booster pumps) develop sufficient pressure to roll the main unit and even to permit it to carry some load over and above the auxiliary power requirements in the station.

If an open feedwater cycle is employed, there are several possibilities. Where the single full capacity feed pump is turbine driven, there is generally a separate motor driven booster pump, designed to develop from 100 to 200 psi pressure. The booster pump is started first and permits building up the boiler pressure to a value sufficient to start rolling the feed pump turbine when it is supplied with live steam from the boiler through its auxiliary nozzle. From here on in, it is essentially a "boot-strapping" operation. As the turbine speeds up, the feed pump adds more and more pressure to that developed by the booster pump, until the boiler pressure is sufficient to start the main turbo-generator. After the main unit is running, the feed pump turbine takes extraction steam in the normal manner, supplementing this as-and-when necessary with live steam at the auxiliary nozzle.

If no motor driven booster pump is used, it becomes necessary to install a separate motor driven start-up pump. Its capacity need only be sufficient to supply steam to the feed pump turbine at start-up conditions. Some utilities have installed such start-up pumps for as much as 600 psi discharge pressure, but normally 200 psi should be found adequate. The only possible exception would be cases where the same pump is used on occasion for reheat attemperation.

If the main feed pump is motor driven, it could certainly be started up on power from an adjacent unit, or even from an outside line if this is the first unit of a new station. This start-up is of course much easier if the feed pump is arranged for variable speed operation.

Finally, if there is insufficient power supply for the initial start using the main feed pump motor, it would be necessary to install a small motor driven start-up pump.

In the case of once-through boilers, it is necessary to circulate approximately one-third maximum flow before the main unit can be started. Therefore, if the full capacity main feed pump is turbine driven, a separate partial capacity motor driven start-up pump must be installed.

Question

What percent availability can be expected from a turbine-generator shaft driven boiler feed pump?

Answer

Actually, the boiler feed pump does not know what drives it. Therefore, as long as the same degree of precaution is taken in selecting the pump, in engineering the application, in initially starting up the unit and in operating it later as in the case of any other drive, there should be no difference in availability.

As a matter of fact, two particular characteristics of main shaft driven installations serve to increase availability over certain other arrangements:

1. The absolute requirement for a separate full pressure hot-restart feed pump automatically provides at least partial standby capacity. In contrast, units have been installed with steam turbine or motor drive with no standby capacity whatsoever.

2. With hardly an exception, main shaft driven feed pumps are supplied with variable speed devices between the pump and main drive, as against some direct connected motor driven pumps. It is a generally accepted fact that operation at variable speed is beneficial to the life and availability of boiler feed pumps.

The foregoing should not be interpreted to mean that the coordination of engineering details is as simple for main shaft drive as for more conventional installations. I definitely stipulated the *same degree of precaution* and not the same "quantum" of effort.

Question

I have heard you speak of super-speed boiler feed pumps in the range of 30,000–40,000 rpm in future applications. What type of drive do you expect will give you these speeds?

Answer

Both turbine and electric motor drive will probably be used in the future for these high speeds. In the case of steam turbines, the impeller of a single stage pump will be mounted on an extension of the turbine rotor shaft. The pump and turbine casings will probably be an integral element, without a stuffing box for the pump. A mixing chamber located between the pump and the turbine will take feedwater and steam in-leakage and then of course bleed off to a lower pressure point in the feed 121 water cycle.

A pump of this type was built by us in the late 1940's for the Navy, although it operated at speeds under 20,000 rpm. We have since then developed the "Turbo-Monobloc Feed Pump" (Fig. 2 and 3) operating at speeds between 10,000 and 15,000 rpm for Marine and Navy application.

For electric motor drive, two solutions present themselves:

a. High frequency electric current

b. Epicyclic co-axial step-up gears

The first is an intriguing possibility in that it might be possible to use some form of electronic frequency converter which would give a variable frequency output as well. This would provide variable speed operation without the necessity of a separate variable speed device.

In either case, the pump impeller would be mounted on an extension of the driver shaft, to eliminate the need of a flexible coupling which would present serious problems at these speeds.

Question

Why is it that the design capacity of condensate pumps seems to include a greater margin over the condensing steam flow of the main turbine than the margin included in the boiler feed pump capacity over the maximum turbine throttle flow? Does this greater margin reflect a greater potential reduction of capacity through wear?

Answer

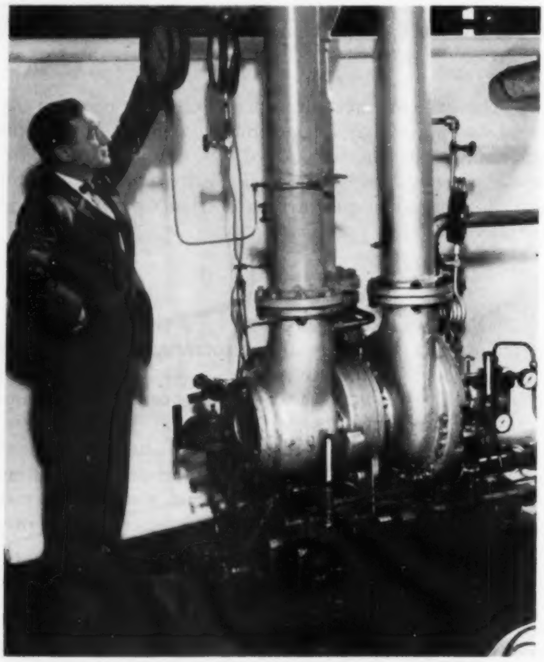
Assuming that adequate care is exercised in the choice of this equipment, in the selection of materials of construction and in the operation of the pumps, there is no reason to expect that the rate of wear—and consequently the ultimate reduction of capacity—will be significantly different for these two services.

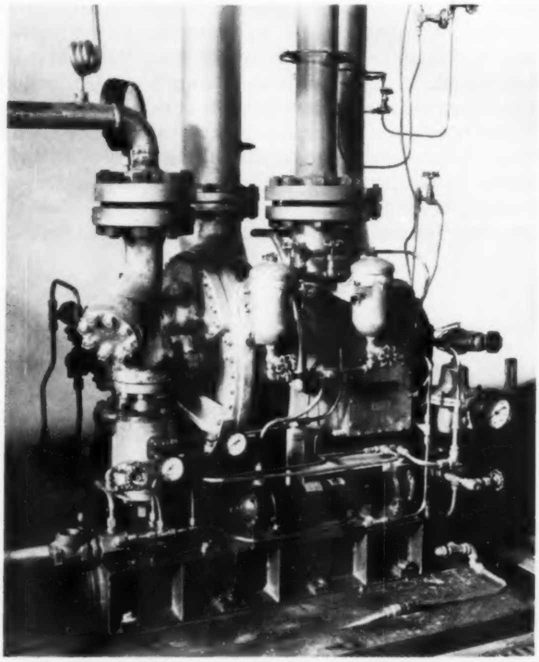
However, the difference between the condensate pump design capacity and the maximum condensing flow includes another factor. Normally, the feedwater cycle provides for the pumping of heater drain returns from the closed heaters. These drains are cascaded on down to the lowest pressure heater which immediately follows the condenser. At that point they are pumped back into the feedwater cycle by a heater drain pump which essentially discharges them in parallel with the condensate pump.

However, provision must be made for two eventualities:

1. Should the low pressure heaters be taken out of service and by-passed, the condensing flow will be increased by an amount approximately equal to the heater drain returns under normal operation.

2. Should the heater drain pump or pumps be out of service for some unexpected reason, the drains from the lowest pressure heater will have to be cascaded into the condenser hotwell.





Figs. 2–3—Both these, above, are views of the author's company "Turbo-Monobloc" pump built to operate at speeds of 10,000 to 15,000-rpm with pump and turbine casings an integral element without a stuffing box for the pump

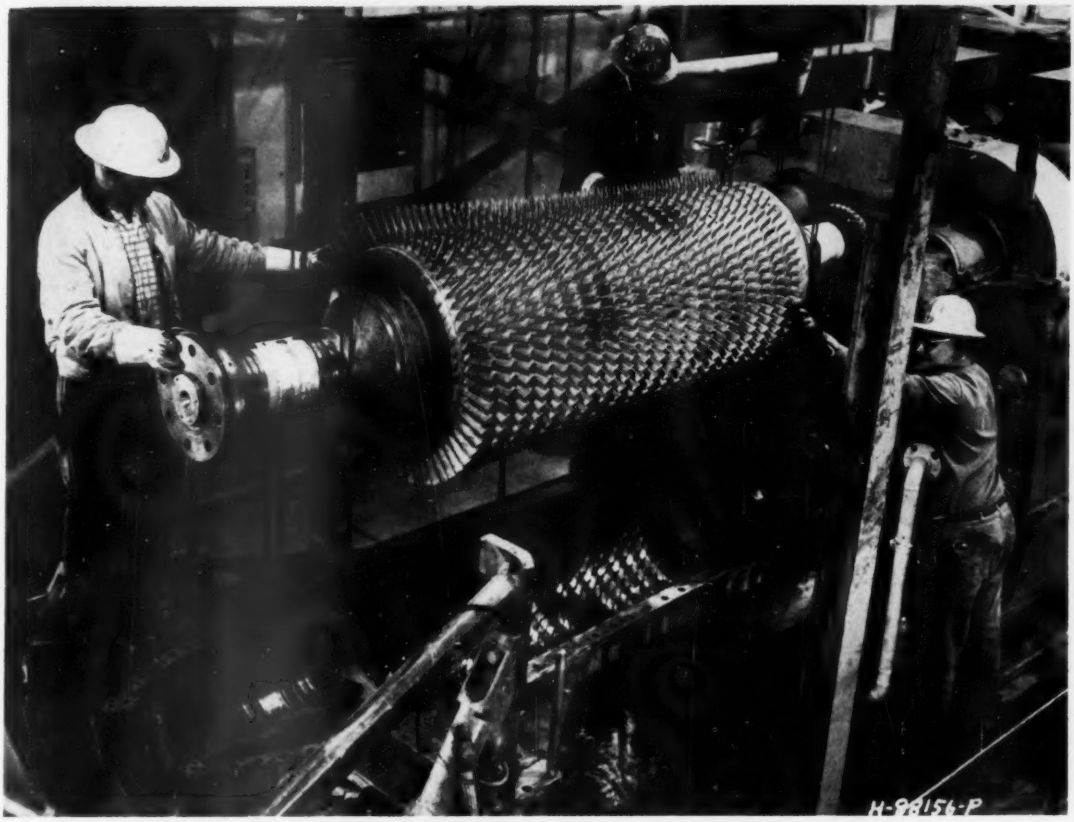


Fig. 6—Bureau of Mines personnel assembling air compressor

Bureau of Mines Coal-Fired Gas Turbine Research Project

By T. Reed Scollon,[1] Harry Perry,[2] Earle P. Shoub,[3] and J. P. McGee[4]

Bureau of Mines, U. S. Dept. of the Interior

(COMBUSTION in April 1960 carried the first report on the Bureau's plans and the set-up at Morgantown, W. Va. Here is a second progress report.)

THE Bureau of Mines, U. S. Dept. of the Interior, is engaged in a comprehensive development program on a coal-fired gas turbine. In 1959, the Locomotive Development Committee (LDC) of Bituminous Coal Research, Inc., terminated its program for adapting a coal-fired, open-cycle gas turbine for locomotive use. LDC, having demonstrated to their satisfaction the feasibility of the unit for locomotive use, offered it to the Bureau for continued studies. The Bureau accepted this offer and is assembling the plant at the Morgantown (W. Va.) Coal Research Center.

Objective of Bureau's Work

The basic objective of the Bureau is to develop a coal-fired gas turbine that can operate for the long periods required for central-station generation of power. The Bureau envisions a combination of the coal-fired gas turbine with the standard steam turbine in a new operat-

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[2] Assistant Chief, Division of Bituminous Coal, Washington, D. C.
[3] Regional Director, Region V, Pittsburgh, Pa.
[4] Project Coordinator, Engineering Research, Morgantown, W. Va.

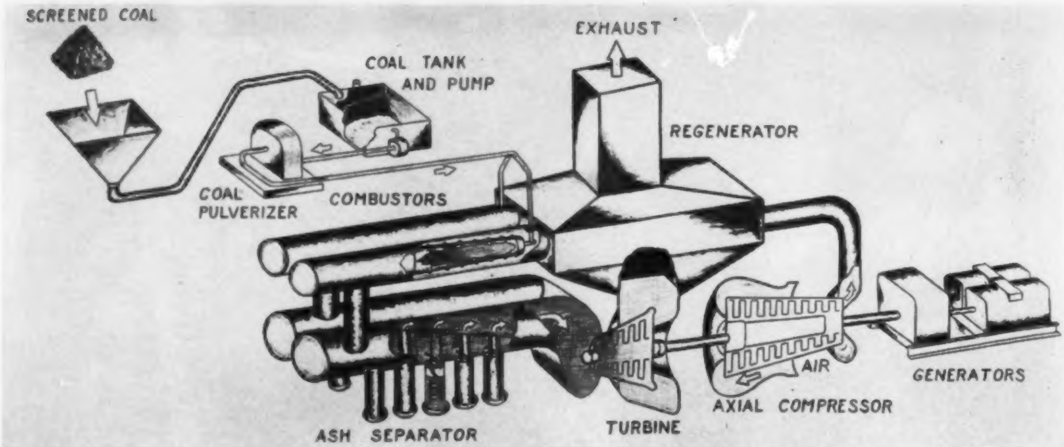


Fig. 1—Schematic diagram of coal-fired gas turbine. Coal crushed to $^3/_{16}$-inch by 0 is pumped to a pulverizer that grinds it to 90-per cent-through-200-mesh. The product is mixed with air and burned in the combustors. Hot high-speed gas from the ash separators drives the turbine, air compressor, and electric generators. Exhaust from the turbine passes through a regenerator that preheats compressed air to the combustors

ing cycle that is 4 to 8 per cent more efficient than today's steam cycle alone. The coal-fired gas turbine could also be used for power generation in water-scarce areas where steam turbines would be uneconomical. To accomplish this, Bureau researchers are making several changes in the coal-fired gas turbine plant in preparation for operating tests at Morgantown.

New Blade Design

Erosion of the turbine blades by coal ash in the hot gases driving the turbine was the most serious detriment to extended operation in the LDC tests. Consequently, the Bureau contracted with the Gas Turbine Division, General Electric Co., to review the results of the previous operations and design a new gas path to minimize erosion. The study[5] did not reveal any major defects in the previous design. Nevertheless, many features of the erosion problem was revealed, and several design changes to decrease erosion of the blades were recommended.

GE made several major design changes that are being incorporated into the design of new stator and rotor blades. First, the shape and arrangement of the blades are being changed so that the ash will move toward the casing instead of toward the roots of the rotor blades. This was done by: (1) increasing the thickness of the trailing edge of the rotor blades and decreasing the thickness of the trailing edge of the stator blades; (2) removing the blades in rotor row 1 and stator row 2 to provide an annular space for ash to centrifuge to the casing; and (3) adding blades to most of the rows in the stator to help stop secondary flow of ash toward the rotor. Second, titanium carbide wear strips are being installed in the base of certain rotor blades and in the

[5] Junge, R. M., and Scheper, G. W., Jr. Locomotive Development Committee Coal-Fired Turbine Blade Erosion Study, No. DF-59-GTD-32. General Electric Company, Schenectady, N. Y., Dec. 18, 1959, 21 pp.

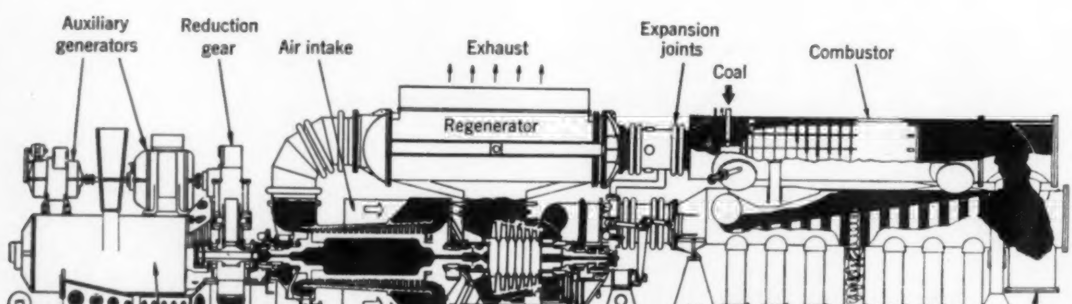


Fig. 2—Cross-section of coal-fired gas turbine. Gas enters the turbine section at about 1300 F. and 60 psig. The 5000 to 5400 rpm turbine generates more than 3000 usable horsepower per hour from approximately 3500 pounds of coal per hour. The air compressor delivers about 60,000 std. cfm at 65 psig

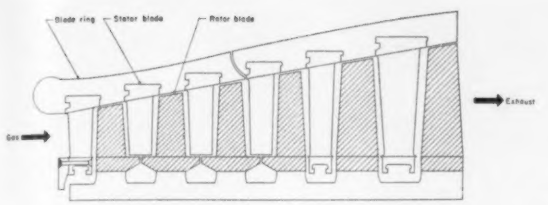


Fig. 3—Gas path through the 6-stage turbine used by LDC in their last 1100-hour run. Ash, concentrated along the rotor, flowed past the tips of the stator blades, undercutting the base of the rotor blades in rows 2, 3, and 4

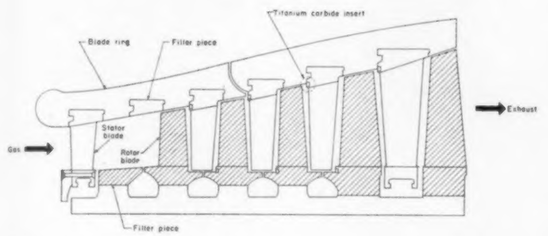


Fig. 4—New blade arrangement to be tested by the Bureau of Mines. The elimination of rotor row 1 and stator row 2 converts the turbine to a 5-stage unit and provides space for ash to centrifuge toward the casing. Blades are cast X-40 alloy with titanium carbide inserts at points of probable maximum wear

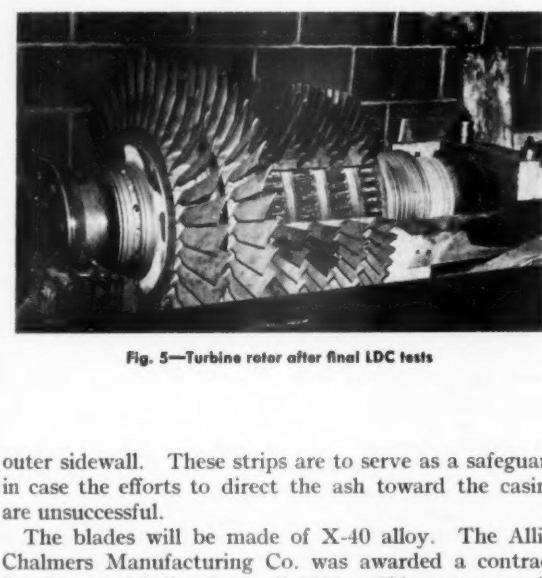


Fig. 5—Turbine rotor after final LDC tests

Fig. 7—During LDC's final 1100-hour run, this rotor blade (arrow) was undercut by ash flowing along the rotor past the tips of the stator blades

Fig. 8—This mock-up shows the new blade design to be tested by the Bureau of Mines. The base of the blade is thicker and there is a strip of titanium carbide at the point of previous severe erosion

outer sidewall. These strips are to serve as a safeguard in case the efforts to direct the ash toward the casing are unsuccessful.

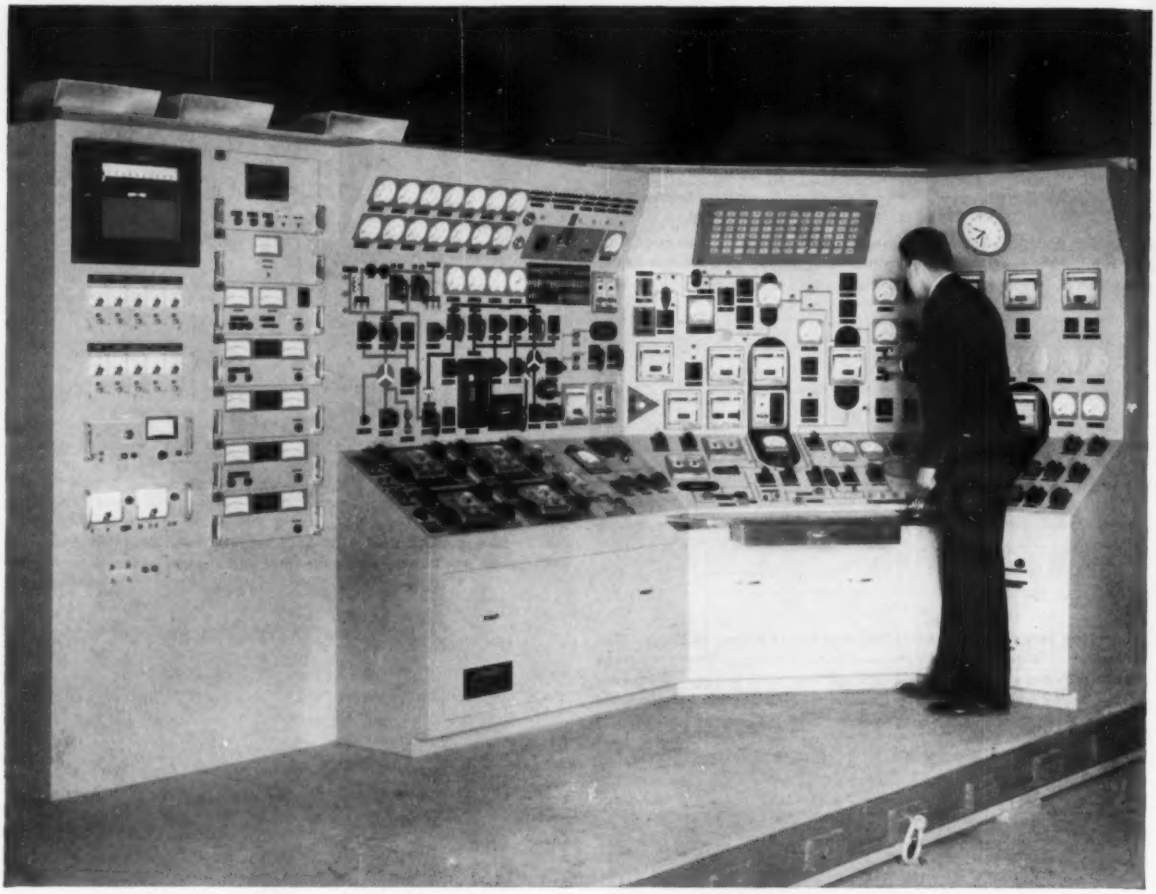
The blades will be made of X-40 alloy. The Allis-Chalmers Manufacturing Co. was awarded a contract for the new blading in April 1961. This contract calls for completion of the work in June 1962. When the new blades are installed, the Bureau will operate the turbine in a 1500-hour coal-fired run. Virtually the same equipment and same operating conditions used by LDC in their last 1100-hr test will be used in the 1500-hour run. This will permit an evaluation of the new blade design.

Coal-Feeding System

Two systems are being readied to feed coal to the turbine during the 1500-hour run. One system includes components developed by LDC to fit in the confines of a locomotive. Size $^3/_{16}$-inch by 0 coal is fed from a bin to a pump that pressurizes and feeds the coal to an attrition-type pulverizer. The 90-per cent-through-200-mesh coal from the pulverizer is fed to the combustors on the turbine.

An alternate system is also being installed. This system includes a Bureau adaptation of a feeder developed to feed coal into a boiler. Coal is metered by a rotating, multi-pocket feeder into a stream of inert gas. The coal-gas mixture is fed to the combustors on the turbine.

The Bureau is working on other phases of the gas turbine process in addition to the turbine itself. Improvements in coal preparation, coal feeding, ash separation, and combustion also are being studied.



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Honor student, Wm. L. Hallerberg, Missouri School of Mines and Metallurgy, joins with W. F. Thompson, president of United Engineering Trustees, Inc., in welcoming former President Herbert Hoover at dedication exercises for the new Engineers' Building in New York City

ASME Annual Meeting Highlights—I

THE Statler-Hilton in New York was bursting at the seams early this month with nearly 5000 registrants at the 1960 ASME Annual Meeting. There were 324 technical papers presented in an excellent program and the social events were once again very enjoyable and successful. In our January issue we will present abstracts of still more papers of exceptional interest to the power field.

Thawing Coal

The recurring and nagging problem of keeping coal moving during the freezing winter months was given a three-paper study. **Joseph J. Bosl** of Cleveland Electric Illuminating Co. presented the first paper, "Electric Infrared Railroad Coal Car Thawing Installation."

He stated that one of the first complete electric infrared railroad coal-car thawing systems in the U. S. was installed at the Avon Lake Plant of the Cleveland Electric Illuminating Co. This system was energized in December 1959 and, one year later, the CEI energized a second electric infrared railroad coal-car thawing system at the Lake Shore Plant. Both systems have operated satisfactorily as designed for 2 years and 1 year, respectively.

The first semi-automatic coal car-thawing installation by the CEI Co. was an oil "hotdog" system built in 1953. When this system was being engineered in 1950 an electric infrared unit was also considered as an alternate method, but did not appear to be economical. In 1955, the CEI engineering department made another evaluation of the electric infrared car-thawing system. At that time, the author's company heard of an electric infrared ore-car thawer built for use in Labrador. Inquiries were made from several of the leaders in electric infrared car thawing as to the possible use for coal-car thawing. None of the manufacturers at that time considered it economical, and the system was never tried.

In 1958 when the Cleveland Electric Illuminating Co. was adding a supercritical steam plant at the Avon Lake Plant the entire field of car thawing was reviewed. Three basic systems were studied for possible use; namely the "oil 'hotdog' system," "the gas infrared system" and the "electric infrared system." Based on results of this study, the electric infrared system was found to be the most economical, with superior operating characteristics.

Wind velocity is a critical factor in designing an electric infrared car system. Although the infrared source is affected little by wind, the object, the car in this case,

is seriously affected, owing to the convection losses of the wind on the side of the cars. For this reason the open end of the car-thawing shed is contoured to the shape of the locomotive. Guarding against wind losses was one of the greatest concerns in designing the system and as a result it was not troublesome.

The metal sheath used as the heating element is quite similar to the element in an electric range. The basic construction is a helical nichrome resistance wire centered in a metal sheath which, in this case, is inconel metal tubing and the nichrome wire is insulated from the tube by magnesium-oxide powder which is compressed to rock-like hardness. The efficiency of the metal sheath is about 80 per cent. The metal sheath requires about 5 min to reach full temperature, which is slow compared to the quartz lamp. Although these are disadvantages there are many other items that are very desirable.

The specifications call for the heating elements to absorb a reasonable amount of physical shock and any thermal shock that would be caused by ice water dripping on the hot elements. It was also specified that the entire installation must be waterproof so that all elements could be either steam cleaned or water washed. The only element to meet these conditions is the metal-sheath heating element. While the quartz element has a higher efficiency it is not waterproof and will absorb very little physical shock.

Flexibility is another big advantage of the electric infrared car-thawing system over other types of car-thawing systems. Starting the electric infrared is very simple—just push the button. With the oil hotdog system, it is necessary to light each hotdog manually with a torch handled by one yard worker, with a second yard man to operate oil and air valves. In the case of the electric thawer, after pushing the button only 5 min are required to warm up the elements. With the oil hotdog system approximately 30 min are required for lighting off. Of course, shutdown again is very simple with the electric infrared system. Merely push the "off" button. In the case of the oil system, with 60 hotdogs, it is necessary to walk the length of the shed, which is 247 ft, to turn off the 60 oil and air valves.

The Avon Lake Electric infrared car-thawing system was a pioneer installation. As a result, the cost of the installation was much higher than succeeding electric infrared car-thawing systems. Even so, for the Avon Lake Plant the total cost per ton of coal thawed for the heating season was approximately 6¢ a ton versus approximately 8¢ a ton for the oil hotdog system. At the Lake Shore Plant where the second installation was installed, the total cost per ton of coal thawed for the season was approximately 5¢ a ton.

In actual operation the thawer handled 10 cars an hour. This was achieved several times when temperatures were near zero and a slight wind blowing. These conditions were close enough to design conditions to assume the installation met guarantees.

Mr. Bosl stated that there was no paint damage to cars the past two winter seasons when the electric infrared thawer was used. In former seasons with hand thawing damage to paint cost the Avon Lake Station $5000 per year. After two seasons of operation of the Avon Lake thawer and one season of the Lake Shore thawer, it can be said that the performance of these two installations has been quite successful. It has been more economical than other systems considering capital, energy, and maintenance costs. The unit is simply and effectively controlled and the operation is relatively troublefree. The design is quite flexible and hence adaptable to varying thawing requirements.

The success of the electric infrared coal-car thawer is a significant milestone in the development of a completely automatic car thawer.

T. C. Sparks of the Toledo, Lorain and Fairport Co., teamed up with **H. L. Zouck,** The Baltimore & Ohio Railroad Co., in the paper "Coal Car Thawing With Gas Infrared and Oil-Fired Units." Since the inception of operations at Lakefront Coal and Ore Docks, Toledo, Ohio, in 1948 a committee of railroad and dock company engineers traveled extensively and studied every conceivable method of car thawing with the aim of improving the original crude and costly methods of track fires, hand torches, steam lances, and the like.

A 300-ft long × 28-ft wide metal shed had been constructed to accommodate a 7-car-length thawing facility. Heat was applied to cars in the shed with 6-in. diam tubes, 5 ft 8 in. long with perforated holes on top, fired by oil burners. These tubes, which have become known as "hotdogs," were installed parallel to track rails in rows of four, two between the running rails and two outside the rails. The rows of hotdogs were spaced with about 5 ft between the rows. The hotdogs between track rails were depressed for clearance by depressing the ties. The hotdogs outside the rails were mounted on metal frames to elevate them about 12 in. above the rail tops for applying a portion of the heat directly to the sides of the cars in addition to the heat they apply under the cars. This arrangement of hotdogs was installed for two car lengths at each end of the shed. Large refractory-shielded burners were installed in the center three car lengths of the shed, 6 units on each side of the track, to apply additional heat to sides of cars.

Through efforts of the committee, these hotdogs were developed to use low-pressure air. It was also determined that hotdog tubes made of steel, wrought iron or cast iron would not last more than about 100 hr, but No. 309 stainless steel would last several seasons.

Fuel consumption of the heating units averaged about 5 gal of oil per hr for each of the 56 hotdogs and 12 gal of oil per hr for each of the 12 refractory heaters, or a total fuel consumption of about 424 gal of oil per hr. Total input was about 59 million Btu per hr and fuel cost about $45 per hr.

The performance of the thawing facilities as thus originally constructed was good but it was recognized that efforts should be made to improve further the design of hotdog heaters and also to obtain a more evenly distributed, effective heat application to car sides.

The first improvement was in design of hot dogs and was developed by the master mechanic at Lakefront Dock. The new hotdog consists of a refractory lower half section molded in a steel casing, and a top half-circle section of perforated No. 309 stainless-steel rolled at a $3\text{-}^5/_{16}$-in. radius. Each hotdog has an input of about 637,000 Btu per hr. This newly developed hotdog, with proper handling, eliminates oil spillage and burning of track ties.

The second improvement was in the method of side-heating cars by installation of infrared equipment, the potentialities of which were satisfactorily demonstrated in tests of January 1956.

This consisted of 36 infrared cabinets, 18 on each side of the track, to replace the 12 refractory heaters and 28 of the hotdogs that were located outside of the track rails. Infrared cabinets were installed and all revisions made in the Fall of 1956.

Present heaters comprise 28 hotdogs between the track rails and 36 infrared cabinets beside the track, consuming about 127 gal of fuel oil and about 95 gal of propane per hr. As compared with the original installation, this reduced the input from 59 million Btu to about 26.6 million Btu and the cost of fuel was reduced from $45 per hr to $26 per hr. It also resulted in about doubling the dumping rate in winter months.

Experience with the present thawing facilities shows that two men are required to turn on and off the infrared cabinets and hotdogs. This might be reduced to one man if equipment is put on automatic push-button controls. Cutting of cars as they enter and leave the thawing area requires an additional man; this may be done by the pusher operator where labor agreements permit. Another man is required to remove and replace air hoses on cars to prevent damage from heat. This man could be eliminated if a satisfactory protective device is used.

A recent addition of eight air vibrators on each car dumper—six on cradle blocks and two under pan—at a relatively nominal cost has greatly accelerated the speed of dumping. These vibrators have a 4-in. piston and give desired results when operating at 40 to 50 psi pressure. At this pressure these units produced 2880 vibrations per min and an impact force of 25,800 lb. Each weights about 105 lb and is about 12 in. high.

The present thawing facility at Lakefront Dock represents an investment, at 1956 construction costs, of about $125,000.

The next paper "Thawing Coal in Railway Cars" was presented by **F. B. Manning** and **E. Szaks** of the Chesapeake and Ohio Railway Co. The Chesapeake and Ohio Railway Co. has extensive coal-handling facilities at Newport News, Va., and at Toledo, Ohio. Facilities at Newport News include one high-lift-type car dumper and five rotary car dumpers. Six ships may be loaded simultaneously. Each of the dumping systems is equipped with an oil-fired car-thawing plant. Oil-fired heater units were originally used on all of the older Toledo coal facilities. These consisted of 84 burners of the "hotdog" type at each of the three high-lift dumper installations. Each burner was constructed of a 7 ft 6 in. length of steel or alloy pipe, lined with an inch of refractory material. Three rows of holes were fabricated in the top surface to allow escape of the flame. A mixing nozzle admitted a diesel oil and air mixture which vaporized and burned within the tube. Each burner had to be lit by a hand torch and frequent adjustment of the oil or the air control valves required the plant to be attended by four attendants or firemen.

The oil-burner-type installation required a tremendous fuel reserve and the constant operation of a large air compressor. Fuel consumption for the 84 burners averaged about 420 gal of oil per hr, with a fuel cost of $61.32 per hr of operation. Thawing the cars with this type plant was very slow and it reduced the efficiency of the dumping operation to about 25 per cent of the normal operating rate. Considerable damage to brake equipment resulted from the blowtorch-like flame from the burners. Occasionally the center sills of the cars warped and the protective paint usually burned off. Hoses for the braking equipment had to be removed before thawing and replaced later. One of the initially installed oil-fired thaw plants was retired in 1957 and replaced with a propane-fired infrared plant.

The Toledo facility is presently equipped with three high-lift dumpers and a new tandem rotary dumper. An all electric thawing plant was installed at the tandem dumper in 1959. Because Toledo covers the entire practical thawing-equipment range this paper is principally confined to the equipment located there.

Although winter operation at Newport News requires frequent use of the thawing equipment, the actual thawing season is quite short. On the other hand the severity of the weather at Toledo is such that the need for thawing usually begins in October and continues through March. Winter operations at Toledo for the past 6 years have averaged about $4^1/_2$ million tons or 68,000 cars during the thawing season. High for this period was 5,878,889 tons or 93,316 cars. Not all of the cars need thawing. For example only 60 per cent of the cars needed thawing during the winter of 1959–60. Primarily this was due to the fact that the months of November and December were quite mild.

The tandem dumpers which are capable of dumping more than 90 cars per hr presented a much greater thawing problem.

Various sources of energy were considered and their advantages and disadvantages are evaluated in the following summary:

1) Steam lances—Undesirable because of boiler size requirement; possibility of steam freezing and presence of condensate which is objectionable by shippers.

2) Electronic vibration—Undesirable because of the high initial cost of equipment and the probable damage to rolling stock. Equipment for large car installation has not been developed.

3) Mechanical vibration—Undesirable because of damage to rolling stock, degradation of the coal and general ineffectiveness.

4) Inductive and resistance heating—Undesirable because of initial cost, power consumption and inability to isolate the cars.

5) Infrared gas heaters—Considered very advantageous. Uses cheap fuel. Is subject to windage losses and natural gas may be curtailed during cold weather when the need is greater. Fuel cost has risen steadily during the past ten years. Propane-fired units could circumvent some of the disadvantages.

6) Electric infrared—Considered very advantageous. Easy to maintain. Favorable initial cost. Rapid heat yield in minimum time. Energy cost has been stable for years. Heat can be directed and can be readily controlled. No fumes or vapors are created. Can be quickly installed or stored.

In order to determine fairly the most desirable source of heat and heater unit, a series of tests was conducted in the company's laboratory and in the field. Visits

were made to other installations and many tests were observed. All sources of energy other than gas and electric infrared units were eliminated.

A $^1/_4$-in. plate, 8 ft by 8 ft was set up as a test specimen for laboratory studies. A total of 24 thermocouples were arranged in a circular, symmetrical pattern, in increments of 1 ft radii, from the center of the plate and over one half of the plate.

A propane-fired infrared heater with ceramic face and with 60-deg aluminum reflectors was tested first. The unit consisted of two rows of four burners mounted upon 20-in. centers. Tests were conducted 15 and 30 in. from the specimen. Heat measurement and effective heat rise were recorded at 3-min intervals.

Next, electric infrared lamps were tested. Lamps consisted of four rows of 17-in. quartz tubes, two per heater, on 11-in. centers. Each heater was provided with an aluminum reflector. The testing procedure was identical to that of the propane-fired heater test.

Based upon time versus temperature yield of the steel plate, a time factor was determined. The result indicated that the electric infrared lamps had a slight advantage over the gas heater, but that this advantage decreased after a relatively short time interval. The quartz lamps, however, were able to deliver instantaneous and intense heat which could be easily controlled.

Fuel consumption for the propane heaters averaged $3^1/_2$ lb per hr, equal to an input of 75,716 Btu per hr for the eight burners.

The electric-heater units operating at 480 and 27.45 amp were found to be more efficient, but power cost was not competitive with propane in terms of Btu yield.

Information gathered from the many laboratory tests revealed many design requirements of the physical thawing plant needed for the high-lift dumper installations. It was found that four rows of four burner units, vertically on 20-in. centers, with a 60-in. spacing between main units would yield the desired temperature for "skin thawing."

Field experience based on a ratio of 1000 cars handled, gave a comparison of an oil-fired thaw plant and a propane-fired thaw plant (with oil-fired undercar burners).

The oil-fired undercar heaters were replaced with 42 horizontal propane-fired, tube-type heaters in time for the 1958 thawing season. The addition required the use of two small 2-hp blower units and two additional propane vaporizers. The all-gas thawing plant went into operation on November 26, 1958, at a total installed cost of $126,800. Two days later a major accident on the dumper caused a shutdown until August 1959.

The authors' experience with the various types of thawing equipment, operating under identical conditions, would clearly indicate that the best coal car thawing system is an electrical one, provided it is not a periodic use facility or if a punitive demand charge is not assessed on the power consumer.

The authors explained, however, that they are still looking into the frozen-coal problem, even though they feel they have an ideal thawing plant. What they are looking for is the elimination of the thawing, perhaps by use of some chemical additive which will not damage the coal or the cars. Here seems to be a field of vast import with a ready market for an economical product that could make thawing plants as obsolete as the steam locomotive.

Quick Starts

The write-off time on the typical power boiler is somewhere in the neighborhood of twenty years. Yet most central station closed-cycle power plants never have a base load life of more than eight to twelve years. As a result of the heavy capital investment coupled with the wide range between base load and peak load many units of very respectable sizes are winding up their operating days as "on-off" units. Since they were never designed for such service the problems are many.

A panel was held consisting of three papers primarily authored by various individuals on the panel but in collaboration with all the participants. COMBUSTION plans to print these papers in their entirety in its January issue. **O. L. Gann,** Illinois Power Co., led off the session "Developing Techniques for Accelerated Starting of Pulverized-Coal-Fired Units" with the paper "System Economics and Operating Procedures."

In essence, the author explored and revealed the techniques developed in the accelerated starting of eight natural-circulation, 285,000 lb/hr, 850 psig, 910 F steam generators. These installations have subsequently operated as peaking units for over two years without incident and have reduced the system off-peak generating costs by approximately $160,000 to date. Furthermore, the results of exploratory tests conducted on a 525,000 lb/hr, 1450 psig, 1005/1005 F controlled-circulation steam generator appear attractive and also indicate a reduction of starting costs, starting time, and elimination of hot banking costs. System studies indicate a fuel savings of approximately $15,000 per year is feasible if this unit is removed from service as required. Under accelerated starting conditions, the steam generators may be safely fired from zero pressure to operating pressure in minimum time with the assistance of appropriately located monitoring devices.

The economics of removing units from service, Mr. Gann declared, may be determined by evaluating the difference in system production costs with and without the highest incremental cost unit in service with appropriate consideration being given to starting, banking, and maintenance costs coupled with manpower alignment.

Should the evaluation merit removing units from service, the period of economical shutdown becomes a function of banking and starts costs. The rate at which units can be safely returned to service also has an important bearing on system flexibility, reliability and economy sales participatation. If high-cost units are to be removed from service frequently, a safe, economical, accelerated starting procedure becomes mandatory.

Several years ago when it became apparent that the addition of new, more efficient units would make it economically feasible to completely remove units from service in the author's company, a research program was instituted to investigate the various aspects of steam generator and turbine starting. The objectives of this program were to: (1) Determine optimum incremental cost data for various combinations of units within the system, (2) establish a safe, minimum time for economically starting steam generators and associated turbines, (3) perfect realistic equipment starting temperature and pressure limitations, (4) consider the effect of accelerated starting and peaking operation on equipment life, and

(5) appropriately evaluate manpower requirements after establishing new starting techniques.

As new techniques were developed, each was reviewed with the various equipment manufacturers and appropriate consideration was given to their recommendations. In addition to receiving the equipment manufacturers' evaluation of each final development, the consultant engineers were kept abreast of all findings in order that appropriate design changes, if any, could be incorporated into future station design.

Experimental work was completed at this station approximately two and one-half years ago and each of the eight boilers and the associated turbines has now been modified for accelerated starting. By the use of the accelerated-starting techniques at this station, intermittent firing to restore boiler pressure has been virtually eliminated. Each boiler and turbine is removed from service or placed in service as required. Since this station presently operates at an average plant factor below 20 per cent this procedure has resulted in appreciable savings in both fuel and manpower. The rate at which boilers can be placed in service has also been reduced. Both time and cost differentials were illustrated by comparing the results for normal and accelerated starts graphically.

G. G. Halfinger, then teamed up with **R. C. Sherrill,** Combustion Engineering, Inc., to explain and describe "Practical Operating Guides." Their findings indicate that under accelerated starting conditions, steam generators can be fired safely to operating pressure with pulverized coal, from either a hot or cold condition, in near minimum time.

The study program was undertaken with the Illinois Power Co. to investigate the various aspects of accelerated starting of steam generators and turbines. The objectives were: (1) To establish a procedure for the determination of steam-generator starting temperature and pressure limitations, (2) to determine the effect of accelerated starting and peaking operations on the component parts of the steam generator, (3) to establish realistic limitations, (4) to establish practical operating guides.

Tests were conducted on eight 285,000-lb-per-hr, 850-psig, 910-F natural-circulation, tangentially fired steam generators supplying steam through a common header to five 40-Mw tandem-compound, double-flow turbines. Each unit has two elevations of pulverized-coal burners, located in each corner of the furnace, with oil warm-up torches located between the two coal burners. Originally no pilot igniters were installed on any of the eight units, but prior to the test series, igniters were installed adjacent to the lower elevation coal burners for flame stability during initial firing.

The turbines were equipped with adjustable cams on the first and second control valves. Through the use of turbine lead valve by-passes, each unit is started and loaded with full control-valve opening, thus providing full arc admission and uniform heating of turbine valve chests.

Because of the success of the tests conducted on the natural-circulation boilers, the testing program was extended to a 525,000-lb-per-hr, 1450-psig, 1005/1005-F superheat/reheat controlled-circulation steam generator supplying steam to a 75-Mw tandem-compound, double-flow turbine. The steam generator is fired by four elevations of coal burners located in each corner of the furnace, with pilot igniters adjacent to each burner. Oil warm-up torches with adjacent pilot igniters are located between the two lower coal-burner elevations. At the time of this test series, the turbine was not equipped with a stop-valve by-pass thereby precluding full control-valve openings during starting.

The foremost consideration in developing techniques for accelerated starting was to be able to establish the minimum quantity of pulverized coal required to sustain combustion when supplemented by small quantities of auxiliary fuel; i.e., pilot igniters. Before lighting off with coal at no-load conditions, flame-monitoring methods had to be established to insure safety.

Having established a preliminary firing practice, correlation of gas and superheater-reheater metal temperatures had to be considered. On the earlier tests of natural-circulation units, the conventional practice of limiting the furnace-outlet gas temperature to 900 F (with a bare, nonaspirated thermocouple) was followed. For the later tests of the controlled-circulation unit, it was decided that the firing rate, and hence the furnace-outlet gas temperature, would be controlled in such a manner that superheater-reheater metal temperatures (measured within the gas pass), would not exceed their temperature limits. A limit of 1025 F was to be used on the final-stage superheater, 1100 F on the reheater outlet pendant, and 850 F on the reheater-inlet pendant. Gas temperatures at the furnace outlet would be related to the metal temperatures to establish a practical operating guide.

With tentative firing procedures established for the steam generator, consideration had to be given to the turbine manufacturer's limitations. The turbine for both test series had the same limitations:

(1) Initial steam temperature to the turbine to equal or exceed the temperature of the steam chest metal.

(2) Temperature differential between inner and outer surfaces of the steam chest not to exceed 150 deg F.

(3) Temperature differential between the outer surface of No. 1 valve bowl and the inner surfaces of Nos 1 and 3 valve bowls not to exceed 150 deg F.

(4) The rate of metal-temperature change not to exceed 125 deg F per 15 min.

The natural-circulation units furnished steam to a header system, not directly to the turbine; therefore, initial steam temperature requirements were to match as closely as possible the header steam temperature.

The guides, the authors explained, are necessarily somewhat general in nature because specific recommendations can only be made for a given unit and a given cycle. However, it is felt that the results obtained on these particular units are generally applicable to all steam generators.

J. A. Donald, Sargent and Lundy, wound up the session with "Plant Design Considerations." The effect on design philosophy for a new unit for "on-off" operation as well as continued high load-high efficiency service would be limited to considerations regarding instrumentation, interlocking and monitoring. Little or no effect would be reflected on plant arrangement and layout except for the slight influence of some new equipment ideas.

Rapid transmission and recording of information (especially boiler and turbine-metal temperatures) is required for protection against operational hazards. The successful use of the data-handling system in developing and improving starting techniques suggests its application for permanent service. Multiple use of a logger with rapid central print-out of temperatures and pressures could go far toward relieving manpower normally assigned to checking such factors. Properly integrated with a protective system, the data logger may in time eliminate night and week-end crews and reduce supervision required for "on-off" operation. The data logger could well become the nucleus of a central control-room information center which would be of enormous benefit in making fast starts more efficient and safer. Undoubtedly, the future trend in plant design will go well beyond the data logger with the application of the computer. The installation of a computer cannot be justified for this specific application. However, if a computer is installed for other reasons it could well be used for quick-start application.

Over the years, users of steam-generating units have been favored with a continuing improvement in the design of boilers. Gone are the sectional headers, the great masses of cast iron and refractories. In their place are found lighter individual elements and new furnace arrangements that have provided flexible designs for all types of operation. Conversely, the turbine manufacturers continue to design the majority of turbine components on a large mass basis. From the aspect of accelerated starts, these massive components are shown to be the limiting factors. Past experience indicates that not only are the larger turbine components, particularly castings, highly vulnerable to damage when subjected to heating and cooling but repairs are extremely expensive. Castings usually require factory repair or even replacement which frequently results in the need of large blocks of costly displaced power.

Some of the equipment that must be given special consideration during the early phases of design was discussed briefly.

Consider the selection of the boiler and the application to accelerated starts. Actually two points must be weighed.

For a hot start the amount of steam generated should be minimal but at elevated temperatures to properly match turbine-metal temperatures and govern the pressure rise.

For a cold start, the turbine metal is cooler and the optimum firing condition is to maintain a higher rate of steam generation with less superheat to coincide with the limits of the turbine manufacturer.

The furnace volume sized on the basis of heat release on one unit tested is fairly conservative (80,000 Btu/sq ft EPRS) and the tests indicate that complications resulting from temperature differentials would not jeopardize accelerated start-ups. Higher heat releases could result in higher metal temperatures and possibly limit firing rate. However, this relationship of heat release to metal temperatures is a function of boiler size and type and must therefore be established for each particular application.

The physical location and flow pattern of the superheat and reheat surfaces are important to obtain good temperature control. Equally important is the gas flow pattern through these sections, particularly at light loads.

It would appear desirable for burner-design modifications on pulverized coal to permit adjustment of flame location and burn-out point in the horizontal as well as the vertical plane.

Another consideration which may be given to the high-temperature steam elements is the possible advent of higher alloy materials.

Gas Side Corrosion

The larger unit size of boilers, the greater quantities of fuels burned have combined to keep the problem of controlling gas-side corrosion front and center in the eyes of plant betterment and operating engineers. Several thoughts on this subject were presented. **L. D. Grames,** and **H. W. Huffcut,** The Air Preheater Corp., reported on a search for a relatively inexpensive material for combined acid resistance and ease of cleaning. This search pointed to the use of procelain enamel on a low-cost base metal. The paper "Enameled Cold End Surface for Low Temperature Service" described these specially formulated porcelain enamels which have resisted acid attack, thereby prolonging the service life of the element, thus opening the avenue for lowering exit-gas temperatures and improving boiler efficiency.

In the build-up of deposits on an air preheater element, both physical and chemical actions are involved. The physical actions include (1) the trapping of the very finest dust particles in the flue gases by the surface of the element owing to its lack of perfect smoothness; (2) the formation of a moist surface due to condensation of flue gases; (3) the further trapping of even fairly large particles by an accumulated deposit; (4) the scouring action, particularly of the larger, harder particles.

The chemical actions chiefly involved the formation of sulfates from acid reactions on the dust, the deposit, and the element when it is not acid resisting.

The three predominant characteristics of all the deposits are partial solubility in water, presence of sulfates, and acidity. The solubilities range from 13 to 98 per cent, the soluble part being mostly sulfates. The higher solubilities occur when the preheater element is readily attacked by acid. The acidities as measured in a one per cent cold-water extract range from a pH of 1.8 to 3.4, the pH depending upon the metal bases of the soluble sulfates.

In general, the bonded deposits on the hotter parts of the heater elements, up to 3 or 4 in. from the cold end, are thin and essentially inconsequential from an operating viewpoint. At the cold end of the corrosion area, however, the deposits readily build up in thickness.

There is a distinct advantage in having a coating that will not readily collect deposit. Extending the period of time between cleanings and shortening the time involved in cleaning is advantageous to plant management. Early tests have indicated that a specially developed enamel is necessary to insure the increased element life that makes it economical. Many enamels have been tested and we have found good ones as well as bad.

To lower exit gas temperature has always been a goal of power plant designers and operators. Several years ago the Detroit Edison Co. designed their No. 3 Unit at River Rouge to achieve an exit-gas temperature of 200 F.

Steam Turbine Controls

By J. D. CONRAD, Jr.†

Westinghouse Electric Corp.

Although the kilowatt rating of steam turbines has grown considerably over the past few years, the fundamental requirements of the control system have remained the same with the exception of additional duties and higher levels of performance in some instances. Nevertheless we publish this paper as a very good status report of value as a reference and a guide

FOR many years the writer's company has used an integrated oil arrangement consisting of speed and load control, high pressure, overspeed and protective devices and lubrication systems. All systems being interconnected and using the same operating fluid.

Before discussing some of the more recent developments in steam controls, a brief review of the oil arrangement is in order. One of two general oil arrangements is used depending on the size of the turbine. On units with ratings up to approximately 125 megawatts, an oil system with a maximum pressure level of 150 psig is used, whereas on larger units with larger valves and higher steam pressures, a main oil pump whose discharge is approximately 325 psig is utilized. The higher pressure oil system will be used as a basis for discussion and only the differences in the two systems will be pointed out.

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High Pressure System

The heart of the high pressure system is the turbine shaft driven main oil pump whose output is used to supply the oil ejector, lubrication system, control system and maintain a back-up supply for the hydrogen seal oil system as shown in Fig. 1. The main pump is

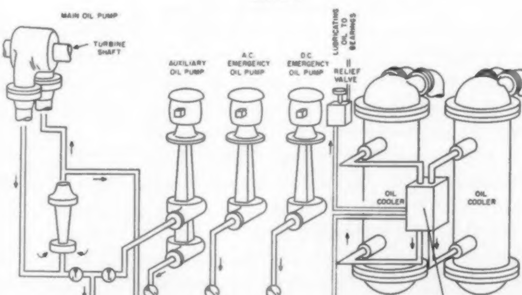


Fig. 1—High pressure and lubrication systems

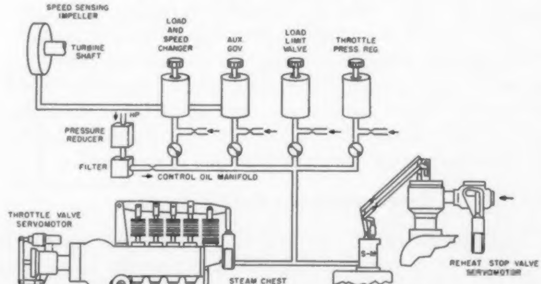
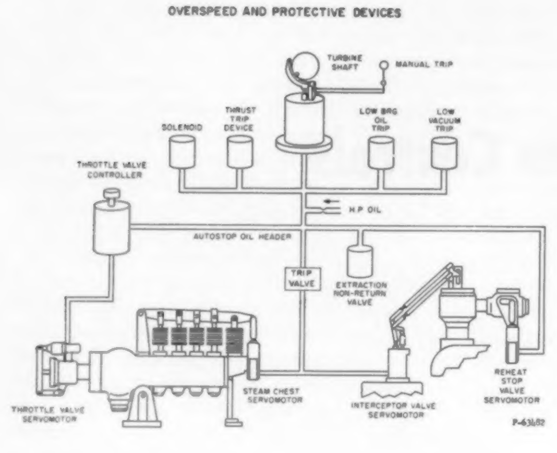


Fig. 2—Primary speed and load control systems



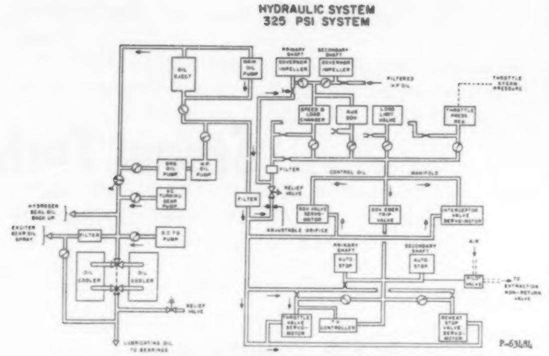


Fig. 3—Hydraulic system—325 psig

←Fig. 4—Overspeed and protective devices

supplied with a positive inlet pressure of approximately 25 psig by an oil ejector that has no moving parts. High pressure oil supplied to the ejector nozzle creates a sub-atmospheric pressure in the ejector body thereby causing additional oil to be "picked up" from the reservoir. For every gallon of oil supplied to the nozzle, approximately one gallon is "picked up" thereby discharging about two gallons. High pressure oil requirements during starting and stopping of the turbine are supplied by one of the two pumps on the auxiliary oil pump shaft.

Lubrication System

During normal operation bearing oil is supplied from the discharge side of the oil ejector at approximately 45 psig as shown in Fig. 1. Accounting for elevation difference between the turbine centerline and the ejector, and pressure losses in the oil coolers, pipes and valves, the supply pressure at the bearings will be about 15 psig. Proper design of the ejector produces the correct bearing pressure with little or no throttling of the bearing oil. This permits a smaller main oil pump as a pressure reduction is not required and energy is not wasted.

During starting and stopping of the turbine, bearing oil is supplied by the lower section of the auxiliary oil pump. Because the high pressure and bearing oil pumps shown on the auxiliary pump shaft are nearly always used at the same time, they are conveniently driven by the same motor.

While the turbine is on turning gear or during an emergency condition, oil is supplied to the lubrication system by either the a-c or d-c emergency oil pumps. As can be seen from Fig. 1, bearing oil can be supplied from any one of four sources. Two bearing oil coolers are used, one for normal operation and a second for standby service. The coolers are connected by a three-way valve that allows the oil system to remain in service while either one of the tube bundles is removed.

Speed and Load Control System

The speed control or governing system is responsible for responding to minute speed changes and converting said speed changes into proper changes in steam flow to maintain constant speed within the limits of the turbine speed regulation. When the turbine is part of a large network, the speed control system becomes a load control system and is responsible for maintaining a constant steam flow to the turbine.

Turbine speed is sensed by an oil impeller mounted on the turbine rotor as shown in Fig. 2. Changes in impeller output pressure resulting from a speed change are amplified at the speed changer and used to position the steam valve servomotors. When the turbine is tied to a large power system and running at synchronous speed, the speed changer becomes a load changer.

In addition to the speed changer, other controllers such as the auxiliary governor, load limit valve and throttle pressure regulator are used as shown in Fig. 3. The controller maintaining the lowest pressure controls the manifold pressure and therefore the interceptor and control valve positions. The auxiliary governor is used to arrest the turbine speed following a sudden load loss and prevent the speed from reaching the setting of the overspeed emergency trip which is generally set at 10 per cent or 11 per cent above normal running speed. The auxiliary governor is responsive to rate of acceleration rather than speed and will come into service when a preset acceleration rate is reached regardless of the turbine speed.

The throttle pressure regulator is sensitive to inlet steam pressure and will cause the steam control valves to begin closing if the steam pressure drops to a preset value. The regulator will close the valves down to the no-load steam flow point if the pressure drops low enough.

The load limit valve is used to set a maximum valve opening or load that the turbine will carry.

In order to provide the controllers with an oil supply of reasonably constant pressure thereby helping to maintain a steady manifold pressure, a "pressure smoothing" device or relief valve is used in the supply line to the manifold as shown in Fig. 3.

It will be noted from Fig. 3 that the interceptor valve servomotors use the same control oil signal as the steam chest control valve servomotors. The servomotors are so set that the interceptor valves will be wide open, or nearly so, when the steam chest valves start to open. Since the interceptor valves are sensitive to control oil manifold pressure and therefore the auxiliary governor, they will close on a sudden speed rise thereby playing a major role in keeping the turbine speed below the over-

speed emergency trip setting. It is important that the steam flow from the boiler reheater be shut off following a large load loss as the entrapped steam in the reheater and associated piping is sufficient to overspeed the turbine.

Overspeed and Protective Devices

In addition to the primary speed and load control system, a secondary or back-up control system exists that protects the turbine-generator from failures associated with either the turbine itself or other station equipment. This system is referred to here as the overspeed and protective devices system and is shown schematically in Fig. 4. This system is built around the autostop oil header whose pressure, when reduced to a sufficiently low value, will cause all of the steam valves to close. Said steam valves include the throttle, steam chest control, reheat stop, interceptor and extraction nonreturn valves.

The autostop oil pressure can be reduced sufficiently to close all the aforementioned steam valves by any one of the following devices.

1—*Overspeed Trip*—This device consists of a hydraulic valve that is operated by an eccentric weight that rotates with the turbine rotor. Should the rotor speed exceed a preset value such as 10 per cent above normal running speed, the weight will protrude and trip the hydraulic valve thereby closing all of the steam valves.

2—*Low Bearing Oil Trip*—This dumps the autostop oil when the bearing oil pressure reaches a preset minimum.

3—*Low Condenser Vacuum Trip*—This device also dumps the autostop oil when the condenser vacuum reaches a preset minimum.

4—*Thrust Trip*—This device determines the approximate position of the turbine rotor relative to the thrust bearing cage. Should this relative position become too abnormal indicating an excessive thrust load, the thrust trip will act to close all of the steam valves by again dumping the autostop oil.

5—*Electric Solenoid.*

6—*Manual Trip.*

When all of the oil systems previously discussed are combined, an arrangement such as that shown schematically in Fig. 4 is obtained for the 325 psig system.

Fig. 5 is a similar schematic diagram for the 150 psig system that is used on turbines of approximately 125 megawatts and smaller. As can be seen, in the 150 psig system the bearing oil is orificed down from the main oil pump discharge and therefore the bearing oil pump portion of the auxiliary oil pump of Fig. 1 is not required.

Also included in the hydraulic portion of the turbine oil system is the hydraulic zero speed indicator which was developed in conjunction with the automatic engaging turning gear. The device produces an elevated oil pressure when the turbine rotor stops. The basic components and the signal characteristics of the zero speed indicator are shown in Fig. 6. Two oil supply nozzles discharge to two receivers through circumferential holes in a turbine rotor mounted disk. When the disk is rotating, the oil jet is continuously interrupted and the pressure in the receiver is maintained at a low value. When the disk stops, the pressure in one or both of the receivers increases as shown in Fig. 6. This oil pressure is the signal used to initiate the automatic turning gear control circuit.

Having discussed the hydraulic portion of the turbine control system let us turn to the steam control segment. That is, the various types of steam valves that are used and some of their design features. Fig. 7 is a schematic diagram showing the location of the valves to be discussed.

Throttle-Stop and Control Valves

To provide double protection in the high pressure steam inlet lines, throttle-stop valves are used in series with the steam chest control valves. The function of the control valves is to regulate precisely the speed and load of the turbine. The throttle-stop valve serves two main functions. First, it acts as an emergency stop valve and secondly, it is used to control the steam to the turbine during the start-up period.

Past practice has been to use separate bodies for the throttle and control valves connected by an elbow as shown in Fig. 8. Present and future practice will be to combine these two valves into one forging as shown in Fig. 8 also. This type combination is being used on units up to about 400 megawatts.

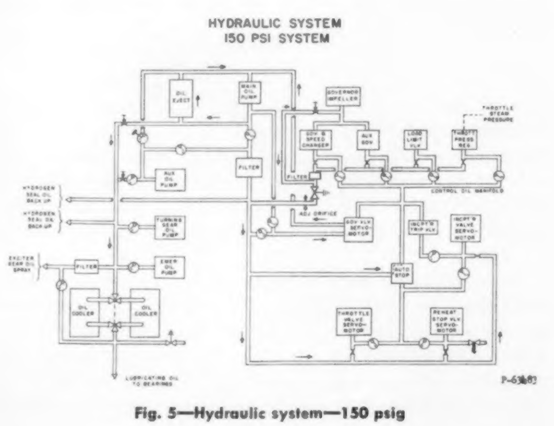


Fig. 5—Hydraulic system—150 psig

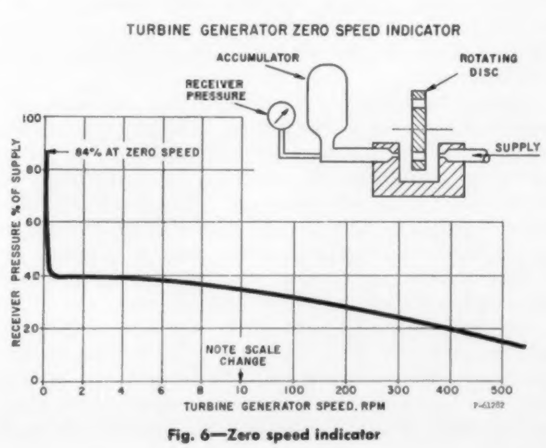


Fig. 6—Zero speed indicator

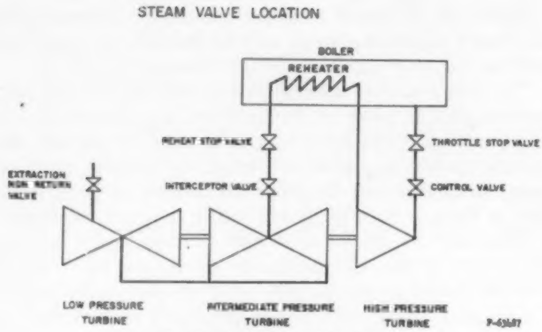


Fig. 7—Steam valve location

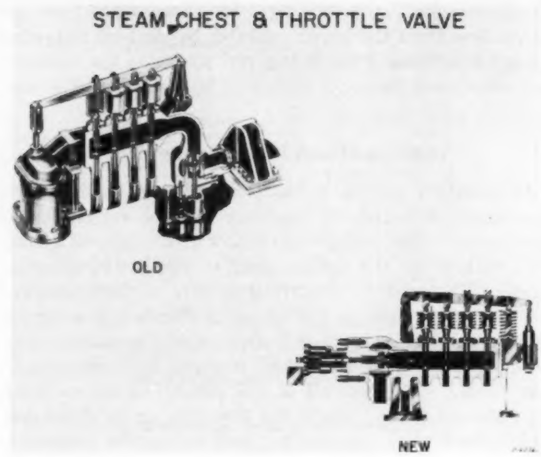


Fig. 8—Steam chest and throttle valve—old vs. new

The throttle valve operates in a horizontal position and incorporates a small bypass valve for starting the unit. The bypass valve is sized to pass approximately 25 per cent of the rated flow at rated pressure with the control valves wide open. The throttle valve has been designed for "back seating" in both the opened and closed positions to reduce stem leakage to a minimum in the wide open position and to facilitate maintaining boiler pressure on short shutdowns. During normal operation, all of the throttle valve operating parts are completely out of the steam flow path.

The steam chest control valves are of the diffuser type and are partially steam balanced to reduce the size of the servomotor and linkage required to lift them. On three and four valve chests up to approximately 400 Mw, all of the valves are lifted by a single external bar as shown in Fig. 8. The servomotor and linkage provides for easy adjustment of turbine speed regulation and valve lifting characteristics.

Overall space requirements for the throttle valve and steam chest has been reduced by combining them and maintenance has been facilitated by having all of the operating parts above the turbine floor line. In comparison to previous designs, the new combination reduces the total angle through which the steam must turn by 180 deg. In order to keep the steam chest as light as possible and still be within design stress limits, the valve seats are made integral with the body forging. Reinforcement of the valve holes is made possible by making the bore of the chest in the shape of an ellipse whose minor axis is vertical.

In order to facilitate handling during shipment and for ease of erection in the field, the combination and its supports are mounted on a bedplate at the time of initial assembly. This bedplate permits the supports to be "cold sprung" before shipment. The supports have been designed to take the cylinder inlet pipe reactions and in addition are capable of carrying the reactions resulting from a pipe system designed, for all practical purposes, to the limits of the ASME pipe code.

For units above approximately 400 Mw, a throttle-stop valve-steam chest combination similar to the one previously discussed, but with a throttle valve on each end, will be used. Fig. 9 shows this steam chest which incorporates separate operating mechanisms for each control valve. The control valves, along with the throttle valves, "back-seat" in the wide open position to reduce stem leakage.

Reheat Stop and Interceptor Valves

To provide the same double protection at the turbine inlet from the boiler reheater, reheat stop valves are used in series with interceptor valves as shown in Fig. 7. As mentioned previously, the interceptor valves are under control of the speed control system whereas the reheat stop valves are responsive to the secondary overspeed protection system.

The reheat stop valve is a power operated swing type check valve as shown in Fig. 10. In order to facilitate opening the valve, a bypass valve is provided to equalize the steam pressure on both sides of the clapper.

The interceptor valve, Fig. 11, is a balanced type valve that is located between the reheat stop valve and the turbine cylinder. This valve contains the temporary and permanent steam strainers. The interceptor valve and reheat stop valve normally operate in the wide open position.

Extraction Non-Return Valves

These valves are located in the turbine extraction lines to prevent the back-flow of steam from the regenerative feedwater system to the turbine. The valves are the swing check type and are either air or oil operated to insure positive closing.

Supervisory Instruments

With the increased complexity associated with higher operating loads, temperatures and pressures, and with the desire to start and load turbines more rapidly, and in some cases automatically, it is essential that the turbine operator have a reliable method of determining what conditions exist at certain points within the turbine at any time.

To determine such conditions as those previously mentioned, a complement of supervisory instruments known as the "Turbo-Graf Line," is being used, Fig. 12. These instruments are capable of both indicating and recording several variables. Continuous records are desirable in that they can be used to establish a normal

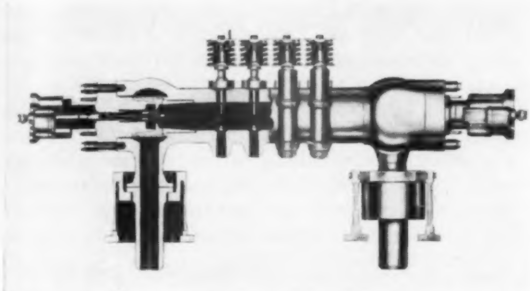
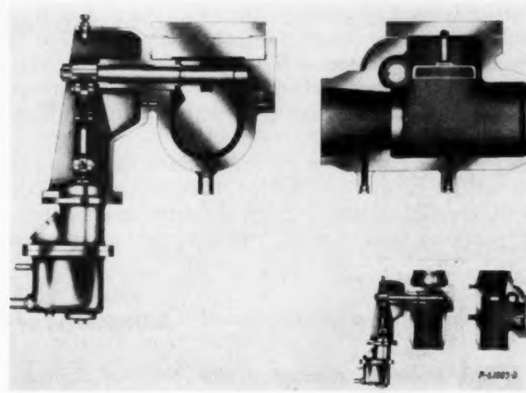


Fig. 9—Double ended steam chest

Fig. 10—Reheat stop valve→



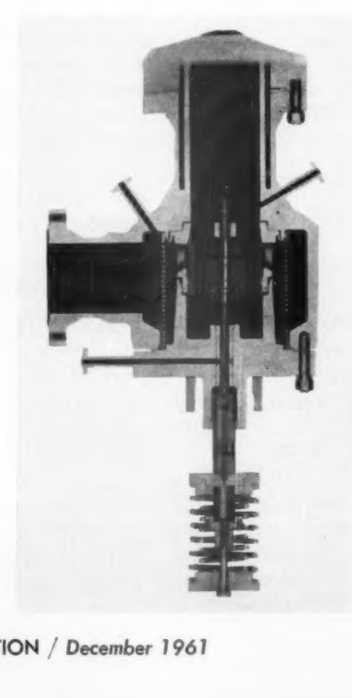
operating pattern for a given unit thus helping the operator to discover any abnormal trends that might develop during either starting and stopping or over a long operational period.

Spindle Eccentricity Recorder—When a turbine is shutdown, it is possible that the rotor may become slightly bowed due to uneven cooling if proper turning gear operation is not maintained. When the unit is started, it is important that the rotor be straight before the speed is increased above a slow roll. The indication of whether or not the shaft is straight is the job of the eccentricity recorder. This instrument consists of two pick-up coils mounted diametrically opposite each other at the end of the spindle. The instrument measures change in air gap distance between the rotor and the pick-up.

Shaft Vibration Recorder—Being able to measure and record shaft vibration at several points on the turbine is important for two reasons. First, it enables the operator to determine whether or not the shaft is balanced at the time of initial starting and secondly, a continuous record of vibration enables the operator to spot any vibration build-up over a long period of time thus indicating possible trouble inside the turbine. The instrument consists of a seismically mounted electro-magnetic pickup whose movable coil is actuated through follower shoes on the turbine-generator shaft. Several pick-ups are generally used to indicate vibration at different points. The record of each pick-up is made on a common chart in successive, periodic intervals.

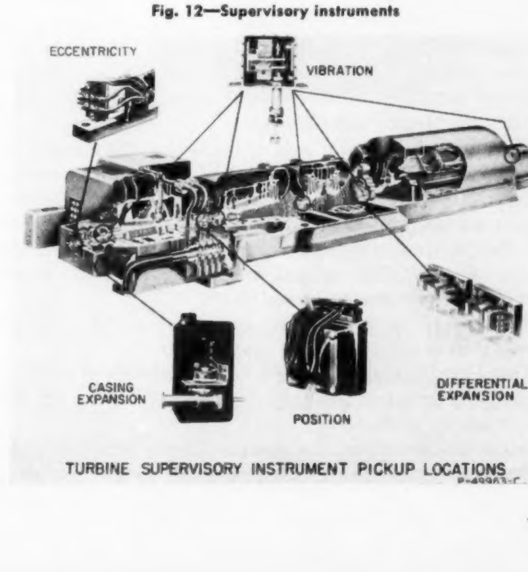
Spindle Position Recorder—This instrument is used to report the axial position of the turbine spindle relative to the stationary parts at the thrust bearing. Excessive spindle movements can be caused by high thrust loads or by wear of the thrust bearing shoes. The instrument pick-up coils are located close to the thrust bearing so that thermal expansions throughout the turbine do not affect the readings.

Cylinder Expansion Recorder—The cylinder expansion



←Fig. 11—Interceptor valve

Fig. 12—Supervisory instruments



recorder is used to measure the total elongation of the turbine cylinders. Since the turbine is anchored at the exhaust end, the recorder pick-up is placed at the opposite or governor pedestal end. The instrument consists of a combination rack and gear that is used to rotate a potentiometer.

Differential Expansion Recorder—Since different parts of a turbine expand at different rates, it is essential that the differential motion between the rotating and stationary parts be known at all times so that proper axial clearances can be maintained despite varying expansion.

Speed and Governor Valve Position Recorder—During starting and emergency conditions, a record of speed is important. When a unit is "on the line," the speed is known to be synchronous and a record of governor valve position is often desirable as a permanent station record.

A combined speed-valve position recorder is available to record speed up to 3550 rpm, governor valve position between 3550 and 3650 rpm and speed above 3650 rpm. Speed sensitive relays select the function to be recorded.

A Discussion of Boiler Lay-Up Periods

At the annual meeting of the National District Heating Assn. this past June a session was held on boiler lay-ups and the following is from a special committee report.

Medium Lay-Up

This type of lay-up was considered to cover the seasonal outage of a boiler.

Naturally more care is taken in these cases because the boiler is to be out of service for several months. In these procedures it must be decided whether an item comes under the heading of boiler lay-up or should be considered as part of normal or preventative maintenance routines.

In this presentation, items that are believed essential to protecting the boiler and its associated equipment while it is out of service are included in the lay-up procedure even though some of them are performed on an annual basis as maintenance items or may be required by law.

Fire Side. The heat-absorbing surfaces of the boilers are cleaned by air, steam or water. One company states that vibration from air driven tube cleaners removes most of the external scale, and another company employs an alkaline water wash with 1% soda ash solution after cleaning with an air lance.

None of the companies reporting use moisture-absorbing chemicals or heat to control humidity within the boiler, most of them rely on air circulation. Two companies dry out the boiler with fire before it is drained.

Water Side. Three of the companies reporting use a wet lay-up and seven use a dry lay-up for the water side of the boiler. The companies that use the wet lay-up use the same chemical concentrations and pH values as they used in the short lay-up.

Cleaning of the water side of the boilers for companies using a dry lay-up is accomplished by pneumatic tube cleaners, turbine brushes, scraping and water washing. One company reports the use of acid cleaning if necessary.

Most of the companies using a dry lay-up paint the inside of the boiler drums with special paints, either Drum Cote or Apexior is used.

Boilers are inspected while out of service at intervals varying from once a week to once a year.

Gas Paths. Gas paths and fans appear to be serviced principally as a maintenance item and not as a part of a boiler lay-up procedure.

Most of the companies clean air ducts, whereas all of them clean gas ducts. This cleaning is accomplished by vacuum cleaning, wire brushing, water washing or scraping.

After cleaning, three companies protect the gas ducts—one with #769 Red Rustoleum, another with a lime slurry spray, and a third uses Silicone #70. A fourth company has unsuccessfully tried several different makes of paint.

I.D. and F.D. fans are cleaned by water washing, vacuum cleaning, air lances or wire brushing, or by various combinations of these procedures. The fan internals are painted by a few companies, most do not.

Instruments and Controls. About half of the companies make no special provisions when instruments and controls were taken out of service. Others observed the following procedures:

- Gages—checked for accuracy, drained
- Water glasses—changed or drained
- F.W. Regulators—overhauled once a year, disconnected or drained
- Meters—overhauled, cleaned and drained or blown down and filled with fresh condensate before the shutdown

Water Makeup Equipment. Chemical feeding equipment used for water makeup equipment, unless it is always in service, is cleaned and left dry.

Deaerators. Deaerators are usually drained, cleaned and left dry, but in two cases are pressurized with 1/2# to 4# steam.

Availability of Boiler. The length of time required to put a 100,000 #/hr boiler in service using this type of lay-up varied from 1 to 6 hours with the mean being 2 1/2 hours.

Long Lay-Up Period

Only 4 companies submitted replies to this part of the questionnaire. Apparently there are not many boilers in this category among the reporting companies.

Conclusions

From the preceding discussion it may be concluded that there have been no radical changes in the methods of laying up boilers or protecting equipment during recent years.

However, it is believed that a presentation such as this given at periodic intervals, where one becomes acquainted with the procedures observed in other compainies, may precipitate investigations into neglected areas in our own companies with beneficial results.

Abstracts from the Technical Press—Abroad And Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd, London, W. C. 1)

Fuels: Sources, Properties and Preparation

The Physico-Chemical Behaviour of Bituminous Coal Structure Components. XIII. The Heat of Decomposition of Bituminous Coal Macerals of Different Rank. C. Kröger and J. J. Das. *Brennst Chemie* 1961, **42** (July), 223–30 (in German).

A newly developed high-temperature calorimeter is described and the results of measurements of heat of reaction of the various macerals as a function of rank and temperature presented. It is shown that the macerals can be distinguished by their heat of reaction. An equation for calculating the decomposition temperature has been deduced.

Integrated Coal-handling Scheme Replaces Obsolete Unit Plants at North Wilford Power Station. J. M. Beskine. *Mech. Handl.* 1961, **48** (Aug.), 423–33.

A detailed description is presented of the unified coal handling recently completed for supplying coal to the B, C, D and E stations and possibly further extensions. The main equipment comprises a traveling wing tripper, a traveling reclaiming crane and hopper, wagon tippler, interconnecting belt conveyors and bulldozers.

Coal Storage and Reclaim. A. S. Drummond. *Pwr. Engng.* 1961, **65** (June), 69–71.

The second part describes two kinds of stackers for very large coal storage plants, a traveling and a swiveling stacker, with bulldozers used for compacting the piles and reclaiming.

Gyroelevator. Anon. *Chem. Proc.* 1961, **7** (Aug.), 36–7.

This device has been developed for the feeding of fine slack coal from storage to the hopper of a chain-grate stoker and consists of a spiral elevator in a tube with one or two agitators with large diameter spirals to loosen the coal and feed it towards the intake of the spiral elevator.

Coal by Pipeline. A. N. Sharp. *Coke and Gas* 1961, **23** (Aug.), 336–8.

A survey is presented of: (1) The development of coal transportation by pipeline in U.S.A., France and Russia; (2) Design calculations, specific gravity and solids content; (3) Pipe materials; (4) The possibility of constructing a network in Gt. Britain to supply coal to power stations from the Midland coal fields; (5) Economic factors.

Heat: Cycles and Transmission

A Review of Heat Transfer Literature 1960 Pt. 2. E. R. G. Eckert, T. F. Irvine, E. M. Sparrow and W. E. Ebele. *Mech. Engng.* 1961, **83** (Aug.), 50–7.

The second part reviews: (1) Convection from rotating surfaces; (2) Combined heat and mass transfer; (3) Change of phase; (4) Radiation; (5) Liquid metals; (6) Low-density heat transfer; (6) Measurement techniques; (7) Heat transfer applications; (8) Thermodynamic and transport properties.

Boiling Heat Transfer. H. K. K. Muthoo. *Chem. Proc. Engng.* 1961, **42** (Aug.), 348–50.

A generalized equation for boiling heat transfer has been developed. Agreement between theoretical and experimental data has been good.

Thermal Radiation Characteristics of Cylindrical Enclosures. E. M. Sparrow, L. A. Albers and E. R. G. Eckert. *A.S.M.E. Preprint* No. 61-SA-23 1961 (June), 7 pp.

Solutions of the radiant flux balance equations are presented for various length to diameter ratios of the cylinder and apparent emissivities. Local and overall heat loss have also been calculated.

Heat Transfer by Simultaneous Conduction and Radiation in an Absorbing Medium. R. Viskanta and R. J. Grosh. *A.S.M.E. Preprint* No. 61-SA-34 1961 (June) 10 pp.

The solution is presented of the problem of simultaneous heat transfer by conduction and radiation between two diffuse, non-black, infinite, isothermal, parallel plates separated by a space filled with a thermal radiation absorbing and emitting medium.

Forced Convection Heat Transfer from a Uniformly Heated Sphere. W. S. Brown, C. C. Pitts and G. Leppert. *A.S.M.E. Preprint* No. 61-SA-26 1961 (June) 8 pp.

An integral method of solution for the local heat transfer of a sphere with uniform heat flux has been developed and the results compared with measurements with water over a wide range of Re and Pr numbers; the agreement is good. From the experimental data average heat transfer coefficients were computed. The problem is of interest in the nuclear field where spherical fuel elements are to be cooled by a liquid or gaseous medium.

Steam Generation and Power Production

The Evaporation Process with Self-Circulation in the Vertical Tubes. E. Kirschbaum. *Chem. Ing. Tech.* 1961, **33** (July), 479–84 (in German).

In the lower part of a vertical evaporating tube steam bubbles are generated which are immediately condensed in the liquid core and thus influence the heat transfer in the whole tube. The tube wall and liquid temperatures were measured and pressures determined subsequently. Conclusions drawn on origin, disappearance or increase of these bubbles, and other movements of the liquid-steam mixture were confirmed by film and slow-motion pictures. It is shown that up to 80 per

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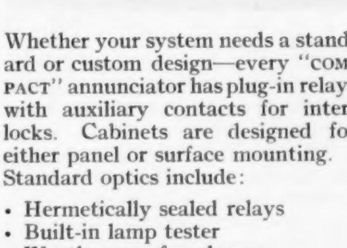

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cent of the total heat available is transferred from the tube to the water by the formation of bubbles and their subsequent condensation.

Pressure Vessels for Gas-cooled Graphite-moderated Reactors. M. J. Noone and R. F. Bishop. *J. Brit. Nucl. Energy Conf.* 1961, **6** (July), 253–65.

The design, fabrication and installation of steel pressure vessels for various reactors are described.

The New High-pressure Cyclone Boiler at Wilton. E. Holmes-Smith, J. Lister and P. V. Liddell. *J. Inst. Fuel* 1961, **34** (Aug.), 307–23.

The boiler is rated at 530 klb/h at 1700 psi and 1065 F and provided with 2 cyclone furnaces in which the primary coal-air mixture is injected at a secant to the tangentially injected secondary air. Each cyclone is directly fed by two beater mills, each supplying alternate ports (6 in all). The slag from each cyclone flows through a discharge slot into a secondary furnace with a slag hole near the front wall and midway between the two cyclones. Details are given of ash fusion points of coals used, auxiliary power required, ash retention, tube erosion and iron attack and measures taken against this, and on pressure drop in the cyclone vortex. Where possible comparison is made with the performance of a pulverized coal fired boiler of the same size and for the same steam conditions.

Czechoslovak Cyclone Furnace for Low-grade Fuels. B. Lumpouch. *Czech. Tech. Digest* (SNTL) 1961, **3** (June), 15–19.

Design details are given of: (*a*) an outdoor vertical-cyclone boiler delivering 75 tons steam per hour at 588 psig and 788 F; its open pulverizing and drying circuit permits a large variety of fuels to be burnt; and (*b*) a horizontal-cyclone boiler delivering 75 tons steam per hour at 940 psig and 932 F equipped with an auxiliary hot-air cycle which effects a 6 per cent saving in fuel.

From C.E.G.B. Digest 1961, **13** (Aug. 5), 2295.

The Vekos-Powermaster Boiler. Anon. *Steam Engr.* 1961, **30** (Aug.), 377–80.

The boiler is designed as a packaged unit for solid fuel firing and consists of a Vekos stoker fitted inside a three-pass dry-back economic boiler. It can use practically any type of coal and achieves efficiencies above 80 per cent without economizer or superheater. The boiler has a built-in multi-cell grit arrester and double-firing of the collected grit and thus conforms to the requirements of the Clean Air Act. It can easily be converted to oil or gas firing or equipped for firing any combination of coal, oil or gas. A table gives test results obtained on a prototype boiler.

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(† *Caskey and Harding,* American Power Conference, 1957).

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Testing of a 3000-kW (th), Liquid-Metal, Model Steam Generator. L. J. Webster, D. E. Fletchall and D. Logan. *A.S.M.E. Preprint* No. 61-SA-46 1961 (June), 12 pp.

Two designs of heat exchangers for transferring heat from liquid sodium to water and steam are described and the results of tests presented. One heat exchanger contained a natural circulation evaporator, the other a kettle evaporator, and both the same superheater. The occurrence of corrosion and weld cracks and their causes are discussed. The heat transfer mechanism in the evaporator and superheater is analysed.

Steam Boiler Damage through Failure of the Automatic Controls. H. Peters. *Tech. Überw.* 1961, **2** (Aug.), 297–301 (in German).

The number of boilers damaged through non-functioning of automatic controls (water level and firing rate) is increasing because insufficient attention is paid to feed water treatment and maintenance of boiler and control fittings. Some typical examples are illustrated. Recommendations are made with regard to improving maintenance schemes and supervision and to better design of controls and their installation.

Repeated Acid Cleaning of Boilers. J. K. Rice. *Combustion* 1961, **33** (July), 45–8.

The occurrence of corrosion in boilers acid cleaned several times, especially those without proper feed water treatment, has been studied. It was found that certain types of organic dispersants in deposits absorb or react with the inhibitor and thus cause the corrosive attack by the acid cleaning medium. It is stressed that acid cleaning should not replace correct feed water treatment.

Water-Side Corrosion and Water Treatment

Feed Water Preparation by Complete Demineralization in the Power Stations of Electricité de France. R. Rath. *Chal. et Ind.* 1961, **42** (July), 207–9 (in French).

Of the 20 most productive French power stations 11 or 63 per cent of the total capacity installed use total demineralization. The first table gives the principal characteristics of these 11 stations (total capacity, steam pressure and temperature, capacity, number of trains and output).

Reducing Corrosion of Power Plant Condenser Tubing with Ferrous Sulphate. T. W. Bostwick. *Corrosion* 1961, **17** (Aug.), 12–19.

Severe corrosion by river cooling water of condenser tubes made of aluminium brass tubes was completely stopped by admixture of ferrous sulfate to the water. Details are given of amounts used, frequency of additions, effect of chlorination, acid cleaning (liquid and foam) on protective layer formation. The causes of the corrosive attack are discussed.

Gas-Side Corrosion and Deposits

Effect of Sunlight on Corrosion. L. C. Rowe. *Corrosion* 1961, **17** (June), 93–4.

High energy ultraviolet light increases the corrosion rate, infra-red light reduces the effect of subsequent exposure to ultraviolet light. Visible light has little effect on corrosion rate.

Introducing Boron Silicide. E. Colton. *Nucl. Engng.* 1961, **6** (Aug.), 324–5.

Boron silicides have a high corrosion resistance once a thin protective boron silicon-oxygen film has formed on the surface. The powder can be formed by oxide bonding or self-bonding and in its final form, e.g., control rods, has an excellent thermal shock resistance.

Ash and Clinker. J. N. Williams. *Pwr. and Wrks. Engng.* 1961, **56** (Aug.), 655–9.

The difference between ash and clinker, the formation of hard and soft clinker and the influence of ash-fusion temperature on the formation of clinker are discussed. Characteristics of pulverized fuel ash and problems involved in its disposal are described.

Power Generation and Power Plant

Detecting Service Failures in Power Plants. Pt. II. Examples. H. Thielsch. *Combustion* 1961, **33** (July), 32–6.

The various types of defects leading to failure are discussed. Examples are given of notches initiating cracks, cracks produced by forming, fabrication, welding or heat treatment, fatigue failures, corrosion, metallurgical "notches" (brittle condition in the metal), incorrect base metals and casting defects. The prevention of these failures by the most suitable detection method is indicated in each case.

Belfast Power Station West. Anon. *Engng. Boil. Ho. Rev.* 1961, **76** (July), 228–33.

The total capacity of this recently completed power station is 240 Mw comprising two 30 Mw and three 60 Mw units with four 180 klb/h and nine 220 klb/h boilers. The small boilers operate at 650 psi and 925 F and are of tridrum design, the larger ones at 950 psi and 925 F, three of single drum and six of bidrum design, all are stoker fired. All boilers are provided with automatic combustion and superheated steam temperature control. The total coal consumption is 2000 t/day or 60,000 t/year. The 30 Mw turbines are two-cylinder, the 60 Mw turbines three-cylinder machines, the former with four, the latter with 5 stages of feed heating. The 30 Mw generators are air-cooled, the 60 Mw generators hydrogen cooled in a closed circuit.

1200 Mw Station for E. Lothian. Anon. *Elect. Times* 1961, **140** (Aug. 17), 239.

Consent is being sought for a 1200 Mw power station near the village of Cockenzie on the Firth of Forth to be supplied with coal at a rate of 10,000 t/day from Monktonhill and Bilston Glen. Four units of 300 Mw each are to be installed.

Refiring Grit at Kingston. Anon. *Elect. Times* 1961, **140** (July 27), 113.

On the chain-grate fired boilers at Kingston power station the proportion of coke breeze in the fuel has been increased from 25 to 65 per cent and the coal used is mainly washery fines and slurry. Oil burners and hot gas recirculation are used to improve ignition. The increased grit is briquetted with low-grade coal and pitch and refired and results in the production of clinkers for which there is a ready sale. The cost per unit sent out is only 0.54 d compared with 0.74 d when burning coal of a C.V. of 10,000 Btu/lb.

Ptolemais Greece's Largest Brown Coal Power Station. Pt. II. Operational Results. T. Geissler. *Energie* 1961, **13** (July), 297–306 (in German).

The characteristics of the brown coal are detailed which caused flame pulsation, delayed combustion and excessive superheater temperature but no deposit formation and a good cleaning of all surfaces, including economizer and air preheater without erosion. To stabilize combustion and reduce ignition time separation of pulverized coal and mill vent gases was introduced, a refractory lining in the burner zone installed and the burner design altered. This resulted in a stable flame down to 20 per cent full load without additional oil firing, constant superheated steam temperature down to 25 per cent full load with a maximum employment of spray desuperheating of 7 per cent and a thermal efficiency at full load of 86

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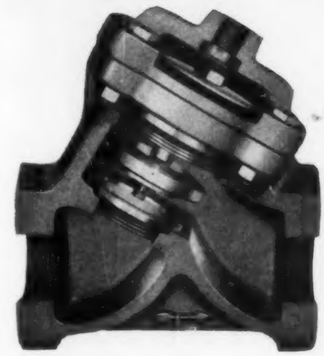

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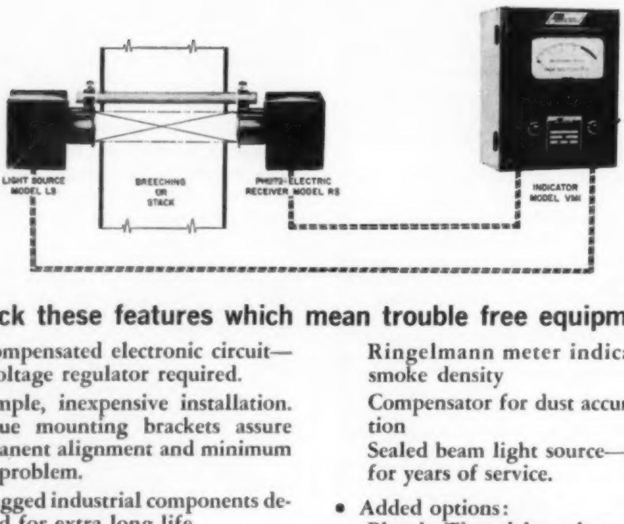

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per cent. It was possible to operate the boiler for over 10,000 h without cleaning.

Putting the Digital Computer to Work at the H. B. Robinson Plant. W. B. Kincaid and H. Wachtel. *Combustion* 1961, **33** (July), 38–44.

The MARC (Monitoring and Results Computer) system installed at the Robinson station of Carolina Power and Light Co. is described. It can scan up to 396 variables at a rate of 5 per second and prints out an alarm if any value is not normal, logs up to 100 variables on 2 typewriters and averages or integrates selected variables every 24 h. It also produces on request, gives a trend record and can make modifications to the stored program. The equations developed for calculating performance are reproduced. The establishment of the computer program and its modifications based on actual performance data is described.

W. H. Sammis Power Plant Unit No. 3 Undergoing Tests. R. L. Criswell. *Heat Engng.* 1961, **36** (May/June), 34–40.

The W. H. Sammis power station of Ohio Edison Co. is planned for a total net output of 692 Mw from four 173 Mw units. Each boiler is rated at 1250 klb/h at 2450 psi and 1050 F with reheat to 1000 F. Superheated steam temperature can be held constant by coolers from $^1/_3$ to full load, reheated steam temperature from $^1/_2$ to full load by by-pass dampers. The boilers are equipped with 15 intervane burners in the front wall supplied with coal from 5 bowl-type mills. Each furnace is subdivided by 2 steam-cooled partition walls into 3 cells, the walls representing radiant superheater surfaces. Difficulties were experienced with steam flow reversal at low loads in some division wall tubes; installation of orifices to increase full load pressure drop was successful.

Heat Power Station with Hot Water Supply over a Long Distance and a Difference in Level of 406 ft. K. Viktorin. *B.W.K.* 1961, **13** (Aug.), 362–8 (in German).

In an Austrian textile firm with several works sited on a small river over a distance of 1.5 miles and a level difference of 406 ft the problem of adequate heat and power supply arose. After extensive studies it was decided to build a new power station at the lowest level with the easiest access to the railway for the incoming coal and fuel oil and to supply the works with high-pressure hot water in closed circuit, an expan-

sion tank under nitrogen pressure at the highest level keeping the system under constant pressure. Two boilers, each rated at 26,500/32,000 lb/h at 925 psi and 935 F supply a 3 MVA turbogenerator operating against a back-pressure of 85 psi. Steam at this pressure is used to heat the water to 320 F, preheat the water for storage and for process in the adjoining works. The flow and return lines are above ground for most of their lengths to save installation costs. The boilers are provided with traveling grate stokers and oil burners for the separate or simultaneous firing of coal and oil but because of the much lower cost of the fuel oil (77 Austrian shillings per 1 $\times$ 10^6 Btu for oil as against 90 Austrian shillings for coal) this has been used exclusively in recent months. A dolomite-like additive is injected into the furnace; neither deposits nor corrosion (high or low temperature) have been experienced during 2 years of operation.

Modernizing a Steam Power Plant. Anon. *Steam Engr.* 1961, **30**(Aug.), 368–73.

The new boilerhouse at the London works of Bryant and May Ltd. contains two horizontal drum, double pass, double header, natural circulation water-tube boilers each rated at 16,000 lb/h at 250 psi and 550 F, equipped with economizer and pressure jet oil burner for a turndown ratio of 4:1 firing 950 sec oil. The thermal efficiency of the boiler exclusive of economizer and air heater is over 80 per cent. The steam is supplied to 380 kw turbogenerator running in parallel with the Grid. Part of the condensate is used in unit heaters for space heating. The exhaust steam from the boiler feed pumps is used either for heating the fuel oil or the feed water.

A Canadian Chemical Company Chooses Coal. Anon. *Coal Utilization* 1961, **15** (July), 8–10.

Coal for the Sarnia works of Dow Chemical Co. of Canada is brought by self-unloading lake ships from Lake Erie up the St. Clair river and discharged into a large hopper at the water's edge from which it is moved by belt conveyor to a cantilevered radial stacker at a rate of 2500 t/h. The stacker can travel through an arc of 150 deg. and repositions itself when a pile has reached a predetermined height. Crawlers and stackers compact the coal and reclaim to a central hopper from which it is transported to a crusher house and thence to the boiler house bunkers at a rate of 440 t/h. The whole coal unloading system is automatically controlled. Two boilers are each

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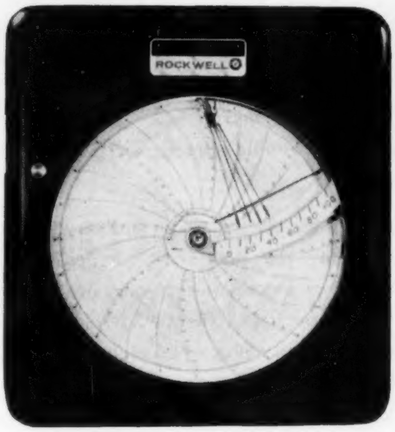

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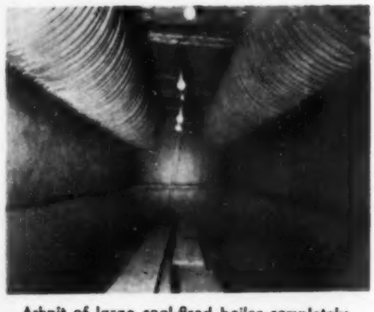

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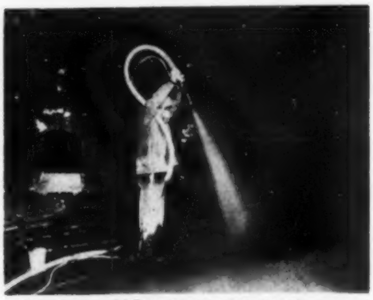

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rated at 300 klb/h at 1415 psi and 880 F, the third at 300.6 klb/h at 475 psi and 935 F, but all operated at 475 psi and 575 F until back-pressure turbogenerators are installed. The boilers are equipped with Turbo Furnaces with liquid slag removal and fly ash refiring.

57 Varieties Rely on Coal. T. S. Spicer. *Coal Utilization* 1961, **15** (May), 14–17.

The greatly increased steam demand of the H. J. Heinz Co.'s food factory at Pittsburgh necessitated the replacement of the old boilers by new ones. First two spreader stoker fired boilers each rated at 70,000 lb/h at 600 psi and 750 F and a thermal efficiency of 82.7 per cent were installed, later 5 boilers rated at 40,000 lb/h at the same steam conditions and an efficiency of 85.5 per cent. These latter boilers are equipped with jet ignition chain-grate stokers which do not require refractory arches but rely on overfire air jets in the front wall for rapid ignition and complete combustion. The $^3/_4$-in. coal is tempered by steam to a moisture content of 10–12 per cent. The steam is expanded in two 3000 kw turbogenerators exhausting at 115 psi and 450 F to the process mains.

Atomic Plant is Announced by PG and E. Anon. *Elect. Wrld.* 1961, **156** (July 10), 54.

Pacific Gas and Electric Co. is applying for a licence to build a 325 Mw gross and 313 Mw net nuclear power station at Bodega Bay. The reactor will be of the direct-cycle, boiling water type with forced circulation and internal steam separation, the fuel 75 t of uranium oxide pellets, 2.5 per cent enriched, in stainless steel tubes. The turbine will receive steam at 1000 psi and 544 F. The thermal efficiency will be 32.5 per cent. It is estimated that power can be produced at 5.62 mills per kwh against 5.77 mills/kwh when using oil and a load factor of 90 per cent.

Materials and Manufacturing Processes

Iron, Carbon Steel, and Alloy Steel. H. S. Link and R. J. Schmitt. *Ind. Engng. Chem.* 1961, **53** (July), 590-5.

A review of the literature published during 1960 dealing with new or improved alloys, their welding and corrosion.

Stainless Steels and other Ferrous Alloys. W. A. Luce and J. H. Peacock. *Ind. Engng. Chem.* 1961, **53** (July), 586–9.

This review of the literature of the past year deals with: (1) General; (2) Corrosion; (3) Mechanical properties and structure; (4) High temperature properties; (5) Welding; (6) Manufacture, metal working and surface treatment; (7) Miscellaneous iron-base alloys.

Corrosion of Carbon and Low-Alloy Steels in Out-of-Pile Boiling-Water-Reactor Environment. D. C. Vreeland, G. G. Gaul and W. L. Pearl. *Corrosion* 1961, **17** (June), 95–102.

Data and metallographic and visual observations of specimens tested in saturated steam, saturated water and a steam-water mixture at 545 F and 1000 psi are reported. No appreciable difference of corrosion rates between carbon steels, high-strength low-alloy and alloy steels were found, but these were higher than those of Type 300 stainless steel.

The Connection of Zircaloy-2 with Stainless Steel for Operation over a Wide Temperature Range. C. G. Duff. *Nucl. Sci. Engng.* 1961, **10** (July), 278–84.

A method of joining Zircaloy-2 and stainless steel using a controlled expansion transition section is described.

Oxidation of Iron-Chromium Alloys at 750-1025 C. D. Lai, R. J. Borg, M. J. Brabers, J. D. Mackenzie and C. E. Birchenall. *Corrosion* 1961, **17** (July), 109–16.

Alloys containing from 0.2 to 10 per cent Cr were exposed in an oxidizing atmosphere to temperatures of 750–1025 C, the corrosion rates measured and the corrosion products examined. Oxidation rates decreased with increasing Cr content, but no simple rate law could be deduced.

High Temperature Aqueous Corrosion of Aluminium-Plutonium and Aluminium Silicon-Plutonium Alloys. H. C. Bowen. *Corrosion* 1961, **17** (July), 12,

The tests carried out in water at 350 C showed that the corrosion resistance increased with increasing Pu percentage. Addition of silicon increased the corrosion resistance.

High Temperature Aqueous Corrosion of Aluminium-Uranium and Aluminium-Silicon-Uranium Alloys. H. C. Bowen and R. L. Dillon. *Corrosion* 1961, **17** (July), 9–11.

Aluminium-uranium and aluminium-silicon-uranium alloys were sheathed in Zircaloy and then exposed to deionized water at 350 C through a $^1/_{16}$ in. hole in the cladding. Al alloys should contain more than 6 per cent uranium, Al-Si alloys with up to 6 per cent uranium were also satisfactory.

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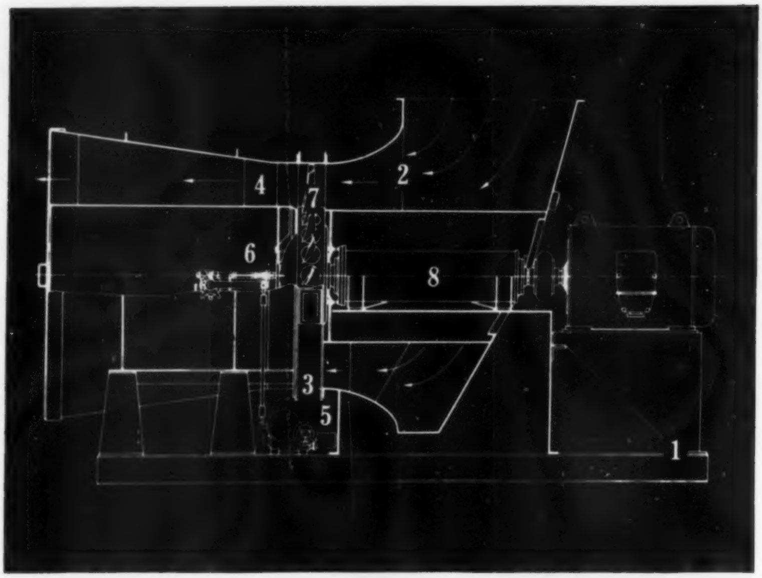

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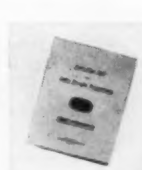
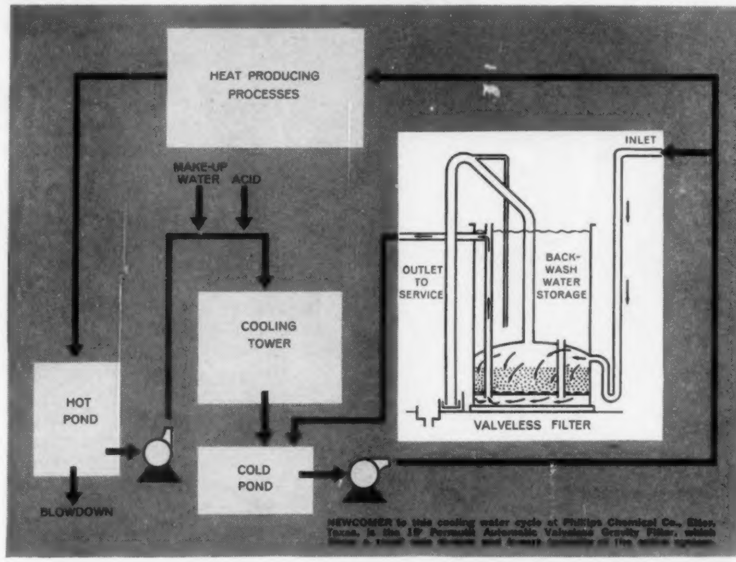


Advertisers' Index

(Continued on page 59)

FLUIDICS* AT WORK



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Here is a new wrinkle in cooling-tower operation:

Side stream filtration. It can appreciably cut your yearly bill for cleaning fouled heat exchanger surfaces and condenser tubes.

Between the cooling-tower and the heat-exchange operation stands a newcomer to the system—a Permutit® Automatic Valveless Gravity Filter.

Its job is to clean up a small portion of the main cooling water stream, roughly 1% to 5%. By continuously filtering this small side stream the turbidity of all the cooling water is reduced and held to an acceptably low level.

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Now in use: Proved in this new application, the Permutit Automatic Valveless Gravity Filter is already saving money for several companies.

All you need, to join them, is a little space near your cooling tower, and a Permutit Automatic Valveless Gravity Filter. For more facts, write: Permutit Division, 50 West 44th Street, New York 36, New York.

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

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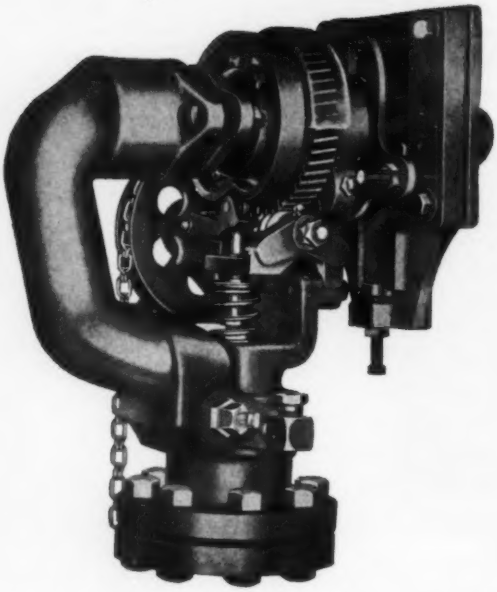

Quick Opening Bayer Soot Blower Valves Assure

- 100% cleaning efficiency
- minimum steam consumption
- superior high temperature resistance

The Bayer Balanced Valved Soot Blower is a single-chain operated design that assures precise sequential operation of the valve and element. *Only* after the start of full steam flow does element rotation commence—a feature which provides positive and efficient cleaning over the entire arc. . .without wasting steam.

The Bayer Soot Blower is simply operated by a pull on the chain which opens the cam-actuated valve. Continued pulling of the chain slowly rotates the element through its cleaning arc, at the end of which the valve automatically closes.

For severe high temperature locations, "super service" elements of Bayer-developed "Chronilloy" are available. Of superior strength, wrap-resistance, and stability, these elements resist the oxidation and chemical action caused by very high temperature gases.

In over fifty years of continuous specialized service, the Bayer company has equipped more than 35,000 boilers with dependable soot blowers. Engineered for long life and low maintenance, Bayer products assure economical and trouble-free operation.

ADVANTAGES OF THE BAYER BALANCED VALVED SOOT BLOWER

- single chain operation
- individual elements adjustable for high pressure service by orifice plate valve
- full steam pressure over entire cleaning arc
- selected gear ratios for optimum rate of element rotation
- minimum pressure drop through valve body
- machined air seal with spring loaded seat
- complete vacuum breaker protection
- precision swivel tube alignment lessens stuffing box packing needs
- load carried on ring type thrust bearings

For further information contact the Bayer representative nearest you. He is an experienced engineer, qualified to service Bayer Soot Blowers.

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